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# SITE-SPECIFIC TECHNICAL REPORT (A003)

for

# BIOSLURPER TESTING AT SITE 24, EDWARDS AFB, CALIFORNIA

by

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for

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August 2, 1996

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## EXECUTIVE SUMMARY

This report summarizes the field activities conducted at Edwards AFB, for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Edwards AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Edwards AFB is one of at least 35 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Edwards AFB were skimmer pumping, bioslurping, and drawdown pumping.

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing, soil sampling, soil gas permeability testing, and in situ respiration testing.

Following the site characterization activities, the pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence: 43 hours in the skimmer configuration, approximately 121 hours in the bioslurper configuration, and an additional 3 hours in the skimmer configuration. Approximately six days after termination of the second skimmer pump test, an additional bioslurper test was conducted for approximately 8 hours. Drawdown pumping could not be performed because of equipment

difficulties. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

Results from the initial skimmer pump test indicated that skimmer pumping was not as effective as bioslurping at recovering LNAPL from this site. Free-product recovery rates decreased steadily during skimmer pumping, beginning at a rate of approximately 52 gallons/day during the initial skimmer pump test and decreasing to approximately 13 gallons/day by the end of the second skimmer pump test. Free-product recovery rates during the bioslurper pump test also decreased after the first day, but remained relatively stable after this time at approximately 50 gallons/day. The second skimmer pump test operated for such a short period of time that it is difficult to evaluate these results.

Groundwater recovery rates during the bioslurper pump test were high in comparison to rates during the skimmer pump tests. On average, groundwater was extracted at rates of 580 gallons/day during bioslurping and 8 gallons/day during skimming.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased significantly at all monitoring points. These results correlate with the 43 ft radius of influence determined during the soil gas permeability test.

Implementation of bioslurping at the Edwards AFB test site probably would facilitate enhanced recovery of LNAPL from the water table and simultaneous in situ biodegradation of hydrocarbons in the vadose zone via bioventing. Bioslurping will result in a vapor stream requiring treatment and the extraction of significant quantities of groundwater; however, the treatment options of utilizing an ICE for vapor treatment and discharging the groundwater for treatment by the Base make bioslurping a cost-effective alternative for long-term remediation.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)

for

BIOSLURPER TESTING AT SITE 24, EDWARDS AFB, CA

August 2, 1996

# 1.0 INTRODUCTION

This report describes activities performed and data collected during a field test at Edwards Air Force Base (AFB), California, to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Edwards AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

## 1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Edwards AFB is one of at least 35 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). Test provisions specific to activities at Edwards AFB were described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing

is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The two LNAPL recovery technologies tested at Edwards AFB were skimmer pumping and bioslurping. The specific test objectives, methods, and results for the Edwards AFB test program are discussed in the following sections.

### 1.2 Testing Approach

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence: 43 hours in the skimmer configuration, approximately 121 hours in the bioslurper configuration, and an additional 3 hours in the skimmer configuration. Approximately six days after termination of the second skimmer pump test, an additional bioslurper test was conducted for approximately 8 hours. Drawdown pumping could not be performed because of equipment difficulties. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

## 2.0 SITE DESCRIPTION

Site 24 is located west of Wolfe Avenue and northeast of Building 3804 (Figure 1). Nine underground storage tanks (USTs) and a drainage ditch are located at Site 24. The four USTs (Tanks M027 through M030) located east of Building 3804 in Area 3807 contained AVGAS (Tank M029) and jet fuel (Tanks M027, M028, and M030). Tanks M028 and M030 failed leak tests in 1990 and are believed to be the source of contamination in the area. A fifth tank (Tank M089), located near

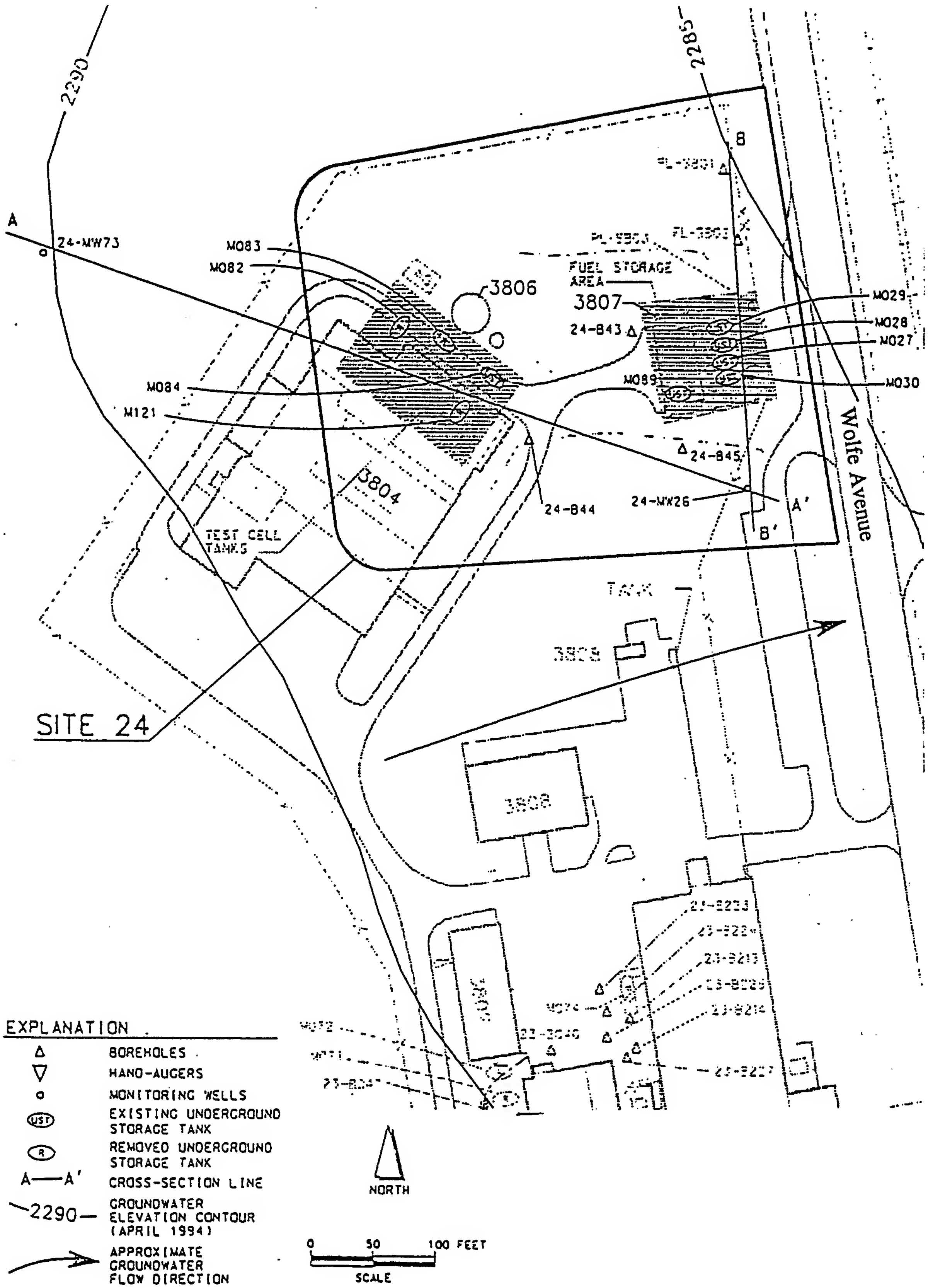


**Figure 1.** **Schematic Diagram Showing Monitoring Well Locations at Site 24, Edwards AFB, CA**

Tanks M027 through M030, leaked approximately one-half of its contents in 1985; however, the tank contents are unknown.

Site soils consist primarily of fine- to medium-grained silty sands with a discontinuous clay layer above the weathered bedrock. Depth to weathered bedrock is approximately 10 ft. Groundwater occurs at a depth of approximately 22 ft.

Free product has been detected consistently in Well 24-MW26. Free-product thicknesses have ranged from 0.07 to 5 ft. Total petroleum hydrocarbons (TPH) have been detected in both soil and groundwater samples. Benzene, toluene, ethylbenzene, and xylenes (BTEX) have been detected in groundwater.

## 3.0 BIOSLURPER SHORT-TERM PILOT TEST METHODS

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at Edwards AFB.

### 3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring well 24-MW26 was evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon™ bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored for approximately 4.5 hours using the oil/water interface probe.

### 3.2 Well Construction Details

Existing monitoring well 24-MW26 was selected for use in the bioslurper pilot testing. The well is constructed of 4-inch-diameter, schedule 40 polyvinyl chloride (PVC) with a total depth of 30 ft and screened at an interval of 15.0 to 30.0 ft below ground surface (bgs). A schematic diagram illustrating well construction details is provided in Figure 2.

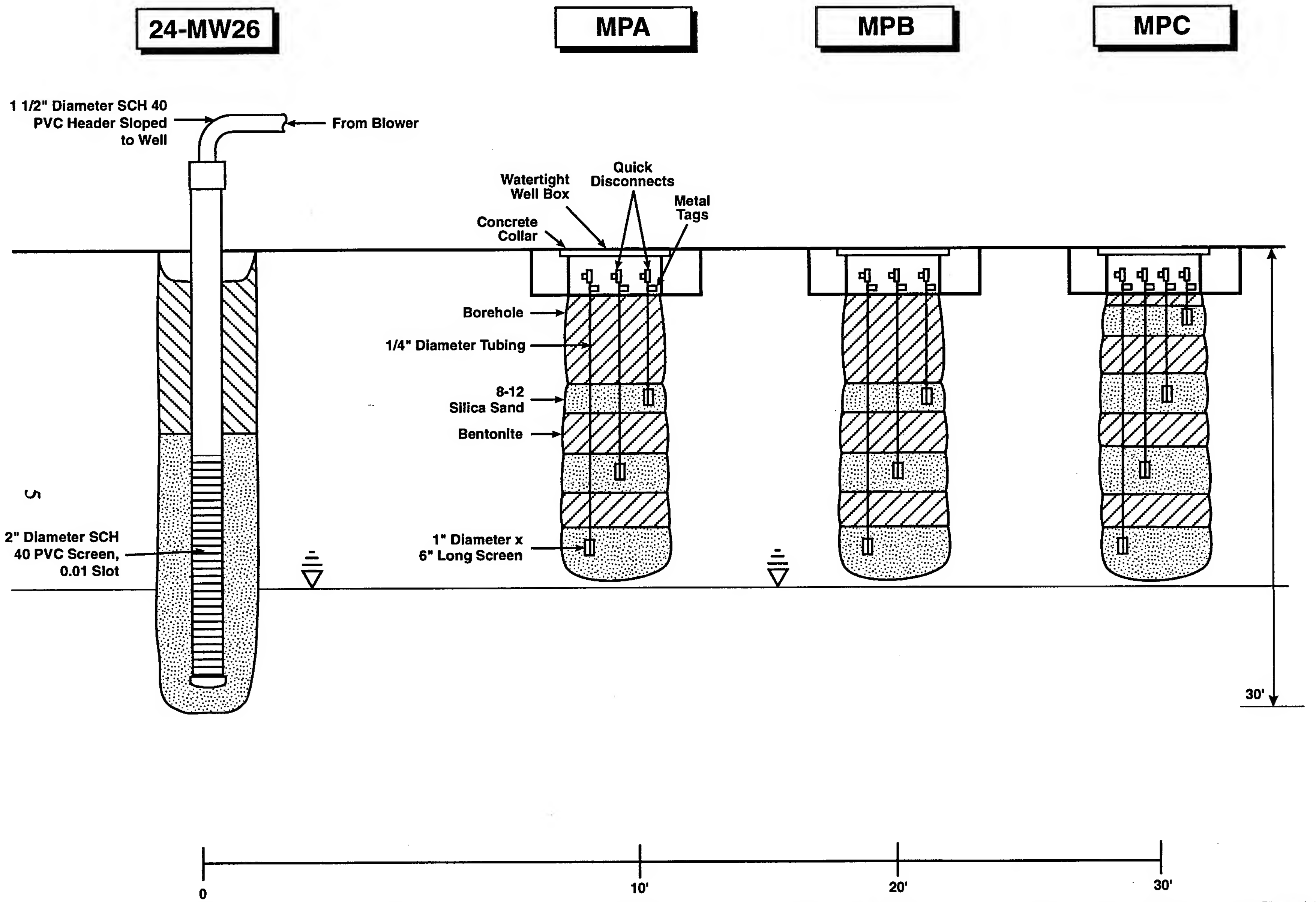


Figure 2. Schematic Diagram Illustrating Construction Details of the Bioslurper Well and Soil Gas Monitoring Points at Site 24, Edwards AFB, CA

### 3.3 Soil Gas Monitoring Point Installation

On October 19, 1995, three monitoring points were installed in the area of monitoring well 24-MW26 and were labeled MPA, MPB, and MPC. Distances from the vent well were 10, 20, and 30 ft, respectively. Construction details of the monitoring points are illustrated in Figure 2.

The monitoring points consisted of sets of ¼-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at the appropriate depths, and the annular space corresponding to the screened length was filled with silica sand. The interval between the screened lengths was filled with bentonite clay chips, as was the space from the top of the shallowest screened length to the ground surface. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal.

All monitoring points were installed in a 6-inch-diameter borehole to a depth of 25 ft. Screened lengths were placed at three depths in all monitoring points: 9.5 to 10 ft, 14.5 to 15 ft, and 19.5 to 20 ft. An additional screened length was installed at a depth of 4.5 to 5.0 ft in MPC. Thermocouples were not installed in these monitoring points.

After installation of the monitoring points, initial soil gas measurements were taken with a GasTechtor portable $O_2$/$CO_2$ meter and a GasTech Trace-Techtor portable hydrocarbon meter. In general, oxygen limitation was observed at the all depths, with oxygen concentrations ranging from 2.8% to 13% and elevated levels of carbon dioxide and TPH (Table 1).

### 3.4 Soil Sampling and Analysis

Two soil samples were collected during the installation of monitoring point MPC. The soil samples were collected from drill cuttings and were packed in brass sleeves. The samples were labeled MPC 3-6 Comp 1 and MPC 3-6 Comp 2 and consisted of composites of soil from 3.0 to 6.0 ft. The samples were placed in insulated coolers, chain-of-custody records and shipping papers were completed, and the samples were sent to Alpha Analytical, Inc., in Sparks, Nevada. Samples were analyzed for BTEX, bulk density, moisture content, particle size, porosity, and TPH. Laboratory analytical reports for all samples are provided in Appendix B.

Table 1. Initial Soil Gas Compositions at Site 24, Edwards AFB, CA

| Monitoring Point | Depth (ft) | Oxygen (%) | Carbon Dioxide (%) | TPH (ppmv) |
|---|---|---|---|---|
| MPA | 10 | 6.9 | 11.5 | 2,600 |
| | 15 | 3.6 | 15.0 | 4,300 |
| | 20 | 12.6 | 13.8 | 15,840 |
| MPB | 10 | 3.9 | 19.0 | 40.0 |
| | 15 | 3.4 | 18.5 | 5,100 |
| | 20 | 4.2 | 12.2 | 9,600 |
| MPC | 5.0 | NM | NM | NM |
| | 10 | 2.8 | 17.8 | 12,800 |
| | 15 | 3.3 | 17.0 | 18,200 |
| | 20 | NM | NM | NM |

NM = Not measured. Moisture content was too high to collect a soil gas sample.

## 3.5 LNAPL Recovery Testing

### 3.5.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 5-hp, 220V, single-phase liquid ring pump), oil/water separator, and required support equipment are carried to the test location on a trailer. The trailer was located near monitoring well 24-MW26, the well cap was removed, a coupling and tee were attached to the top of the well, and the slurper tube was lowered into the well. The slurper tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping as described in Sections 3.5.2, 3.5.3, and 3.5.5, respectively.

The ICE used for vapor treatment at Edwards AFB was a Remediation Services Inc., Model S.A.V.E. system, with a 4 cylinder engine. The ICE was designed to drive a 25 kW generator to provide electrical power for the liquid ring pump. To begin operation of the liquid ring pump, the

ICE is started on 100% supplemental fuel and operated at the proper rpm to generate 60 Hz power. The liquid ring pump is then started and vapor, liquid fuel, and water are extracted from the bioslurper well. Liquid and vapor are separated in the liquid ring pump seal water reservoir, liquid gravity-drains through a filter box to the oil/water separator and vapor is directed to the intake of the ICE. The ICE supplemental fuel is then reduced to allow for complete combustion of the extracted soil gas vapors. The well vapor/supplemental fuel ratio is automatically controlled by the ICE to maintain the proper engine operating rpm to generate 60 Hz power.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

### 3.5.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface with the wellhead open to the atmosphere via a PVC connecting tee (Figure 3). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on October 17, 1995, to begin the skimmer pump test. The test was operated continuously for approximately 43 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

### 3.5.3 Initial Bioslurper Pump Test

Upon completion of the skimmer pump test, preparations were made to begin the bioslurper pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface, as in the skimmer pump test. However, in contrast to the skimmer pump test, the PVC connecting tee was removed, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 4). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or

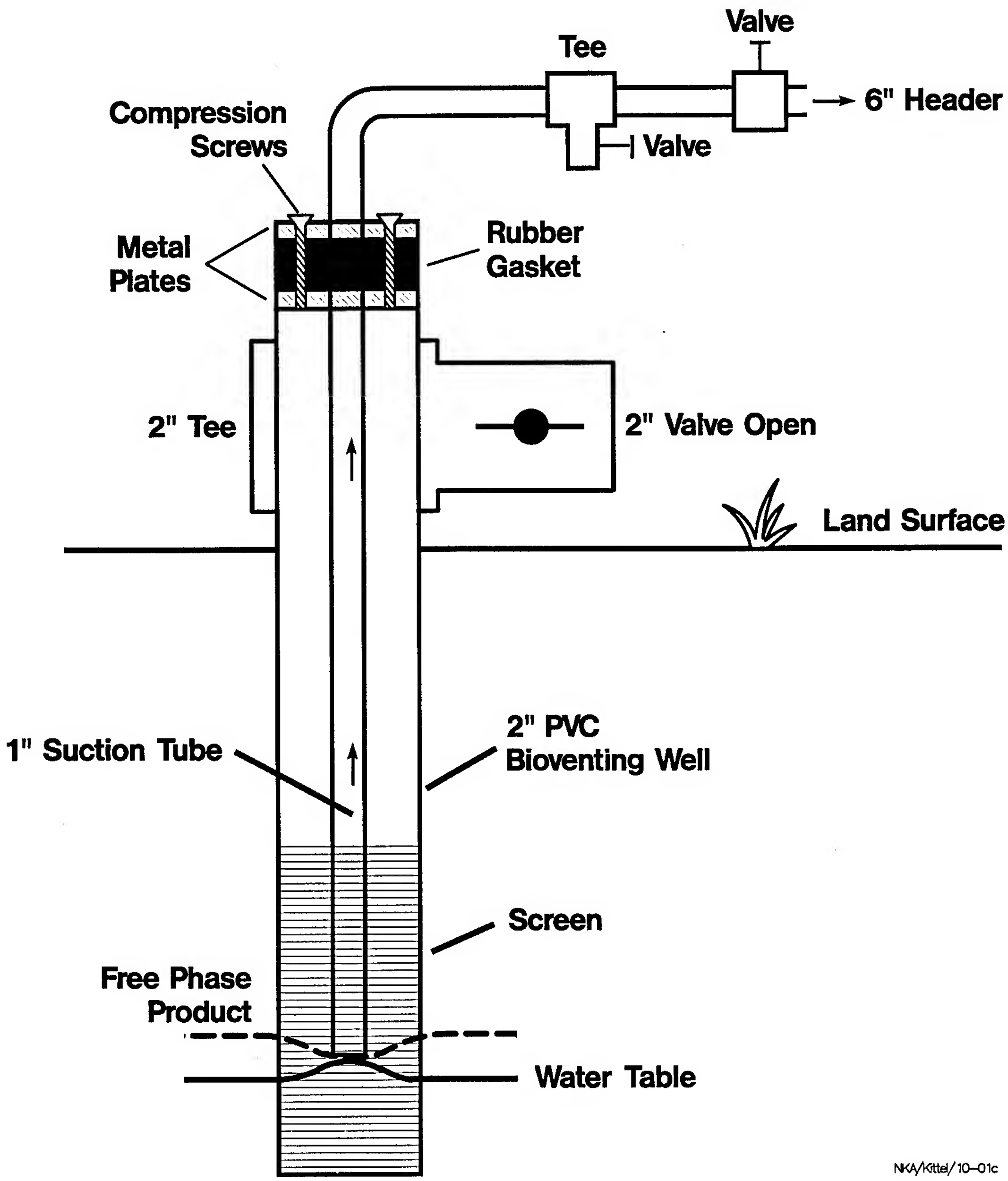


Figure 3. Slurper Tube Placement and Valve Position for the Skimmer Pump Test

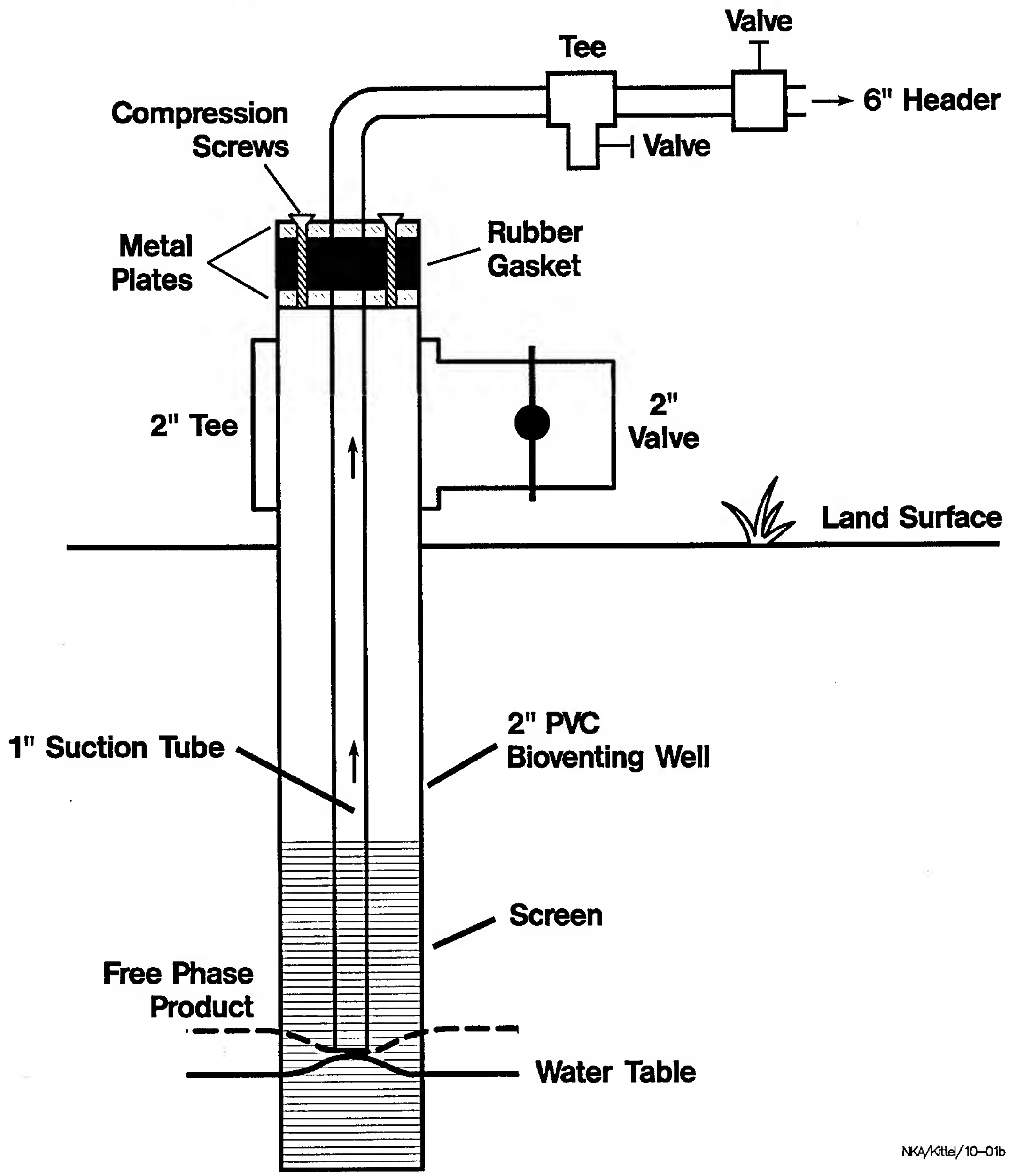


**Figure 4. Slurper Tube Placement and Valve Position for the Bioslurper Pump Test**

groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on October 20, 1995, to begin the bioslurper pump test. The test was initiated approximately 19.5 hours after the skimmer pump test and was operated for approximately 121 hours. Two interruptions in operation of unknown duration occurred during the bioslurper pump test. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

An LNAPL sample was collected one day after initiation of the bioslurper pump test and was labeled EAFB-F1. The sample was sent to Alpha Analytical, Inc., Sparks, Nevada for analysis of BTEX, TPH, and boiling point fractionation.

### 3.5.4 Second Skimmer Pump Test

Upon completion of the bioslurper pump test, preparations were made to begin the second skimmer pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The valve and slurper tube configuration were identical to that used for the initial skimmer pump test. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on October 25, 1995, to begin the second skimmer pump test. The test was initiated approximately 15 minutes after the bioslurper pump test and was operated continuously for 3 hours. The short duration of this test was due to difficulties with the ICE. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

### 3.5.5 Drawdown Pump Test

The drawdown pump test was not able to be performed at the site due to system difficulties which also interrupted the completion of the second skimmer pump test.

### 3.5.6 Second Bioslurper Pump Test

A second bioslurper pump test was conducted to verify the equipment was in proper working order before turning the system over the Base personnel for continued operation. The valve and slurper tube configuration were identical to that used for the initial bioslurper pump test. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on October 31, 1995, to begin the second bioslurper pump test. The test was initiated approximately 6 days after the bioslurper pump test and was operated continuously for approximately 8 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

### 3.5.7 Off-Gas Sampling and Analysis

Five soil gas samples were collected from the bioslurper off-gas during the bioslurper pump test. Duplicate samples were collected in Summa™ canisters prior to and after treatment through the ICE. Samples were labeled EAFB-A2 (prior to ICE treatment) and EAFB-A1 and EAFB-A4 (after ICE treatment). Additional samples were collected from the top of the bioslurper stack, consisting of ambient air. These samples were labeled EAFB-A3 and EAFB-A5. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

### 3.5.8 Groundwater Sampling and Analysis

Six groundwater samples were collected during the bioslurper pump test. All samples were collected from the oil/water separator discharge and were labeled as follows: EAFB-W1, EAFB-W2, EAFB-W3, EAFB-W4, EAFB-W5, and EAFB-W6. Samples were collected in 40-mL septa vials containing HCl preservative. Samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH.

### 3.6 Soil Gas Permeability Testing

The soil gas permeability test data were collected during the bioslurper pump test. Before a vacuum was established in the extraction well, the initial soil gas pressures at the three installed monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well which was the starting point for the soil gas permeability testing. Soil gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil gas pressure data were collected frequently during the first 20 minutes of the test. The soil gas pressures were recorded throughout the bioslurper pump test to determine the bioventing radius of influence. Test data are provided in Appendix E.

### 3.7 In Situ Respiration Testing

Air containing approximately 1.6% helium was injected into four monitoring points for approximately 25 hours beginning on October 27, 1995. The setup for the in situ respiration test is described in the *Test Plan and Technical Protocol a Field Treatability Test for Bioventing* (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through the following monitoring points at the depths indicated: MPA-15.0′, MPB-20.0′, MPC-5.0′, and MPC-15.0′. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The respiration test was terminated on October 31, 1995. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix F.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate of helium diffusion. As a general rule, we have found that if helium concentrations at test completion are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

## 4.0 RESULTS

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at Edwards AFB.

### 4.1 Baildown Test Results

Results from the baildown test in monitoring well 24-MW26 are presented in Table 2. A total volume of 29.5 L (7.79 gallons) was removed by a peristaltic pump and hand bailing from monitoring well 24-MW26. The LNAPL thickness recovered rapidly to approximately initial levels by the end of the 4.5-hour test period. These results indicated that monitoring well 24-MW26 was suitable for bioslurper field testing.

**Table 2. Results of Baildown Testing in Monitoring Well 24-MW26**

| Date-Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|---|---|---|---|
| Initial reading 10/16/95-1552 | 26.55 | 21.50 | 5.05 |
| 10/17/95-1202 | 26.68 | 21.59 | 5.09 |
| 10/17/95-1339 | 25.56 | 22.88 | 2.68 |
| 10/17/95-1342 | 25.42 | 22.67 | 2.75 |
| 10/17/95-1403 | 25.03 | 22.74 | 2.29 |
| 10/17/95-1413 | 24.73 | 22.31 | 2.42 |
| 10/17/95-1459 | 24.62 | 22.06 | 2.56 |
| 10/17/95-1633 | 24.95 | 21.93 | 3.02 |

### 4.2 Soil Sample Analyses

Table 3 shows the BTEX and TPH concentrations measured in soil samples collected from Site 24. TPH concentrations were relatively high with an average concentration of 715 mg/kg. The

Table 3. BTEX and TPH Concentrations in Soil Samples from Site 24, Edwards AFB, CA

| Parameter | Concentration (mg/kg) | |
|---|---|---|
| | MPC 3-6 Comp 1 | MPC 3-6 Comp 2 |
| TPH | 970 | 460 |
| Benzene | <0.070 | <0.050 |
| Toluene | <0.070 | <0.050 |
| Ethylbenzene | 0.073 | 0.055 |
| Xylenes | 0.59 | 0.32 |

average total BTEX concentration was 0.52 mg/kg. The results of the physical characterization of the soils are presented in Table 4.

## 4.3 LNAPL Pump Test Results

### 4.3.1 Initial Skimmer Pump Test Results

The LNAPL thickness prior to the initial skimmer pump test was 3.02 ft (Table 5). A total of 56 gallons of LNAPL was recovered during this test, with an average recovery rate of 32 gallons/day (Table 6). A total of 13 gallons of groundwater was extracted during this test (Table 6). Results of LNAPL recovery versus time are shown in Figure 5.

### 4.3.2 Initial Bioslurper Pump Test Results

LNAPL recovery rates increased significantly during the bioslurper pump test (Figure 5). The increase in recovery rate indicates that LNAPL was mobilized to the extraction well under vacuum-enhanced conditions. A total of 290 gallons of LNAPL and 2,400 gallons of groundwater were extracted during the bioslurper pump test, with daily average recovery rates of 71 gallons/day

Table 4. Physical Characterization of Soil from Site 24, Edwards AFB, CA

| Parameter | | Sample | |
|---|---|---|---|
| | | MPC 3-6 Comp 1 | MPC 3-6 Comp 2 |
| Moisture Content (%) | | 8.6 | 10.6 |
| Porosity (%) | | 69 | 72 |
| Specific Gravity ($g/cm^3$) | | 0.82 | 0.74 |
| Particle Size | Gravel (%) | 0 | 0 |
| | Sand (%) | 83 | 72.6 |
| | Silt (%) | 5.4 | 17.3 |
| | Clay (%) | 11.6 | 10.1 |

Table 5. Depths to Groundwater and LNAPL Prior to Each Pump Test

| Test | Test Start Date | Depth to LNAPL (ft) | Depth to Groundwater (ft) | LNAPL Thickness (ft) |
|---|---|---|---|---|
| Initial Skimmer Pump Test | 10/17/95 | 22 | 25 | 3.0 |
| Bioslurper Pump Test | 10/20/95 | NM | NM | NM |
| Second Skimmer Pump Test | 10/25/95 | NM | NM | NM |

NM = Not measured.

## Table 6. Pump Test Results at Site 24, Edwards AFB, CA

| Recovery Rate (gal/day) | Initial Skimmer Pump Test | | Initial Bioslurper Pump Test | | Second Skimmer Pump Test | | Second Bioslurper Pump Test | |
|---|---|---|---|---|---|---|---|---|
| | LNAPL | Groundwater | LNAPL | Groundwater | LNAPL | Groundwater | LNAPL | Groundwater |
| Day 1 | 52 | 16 | 110 | 580 | 120 | 0 | 73 | 570 |
| Day 2 | 13 | Minimal | 46 | NM | NA | NA | NA | NA |
| Day 3 | NA | NA | 51 | 470 | NA | NA | NA | NA |
| Day 4 | NA | NA | 43 | 660 | NA | NA | NA | NA |
| Day 5 | NA | NA | 83 | 560 | NA | NA | NA | NA |
| Average | 32 | 8 | 71 | 580 | 120 | 0 | 73 | 570 |
| Total Recovery (gal) | 56 | 13 | 290 | 2,400 | 15 | 0 | 24 | 190 |

NA = Not applicable.
NM = Not measured. Equipment malfunctioned and a reading could not be obtained during the second day.

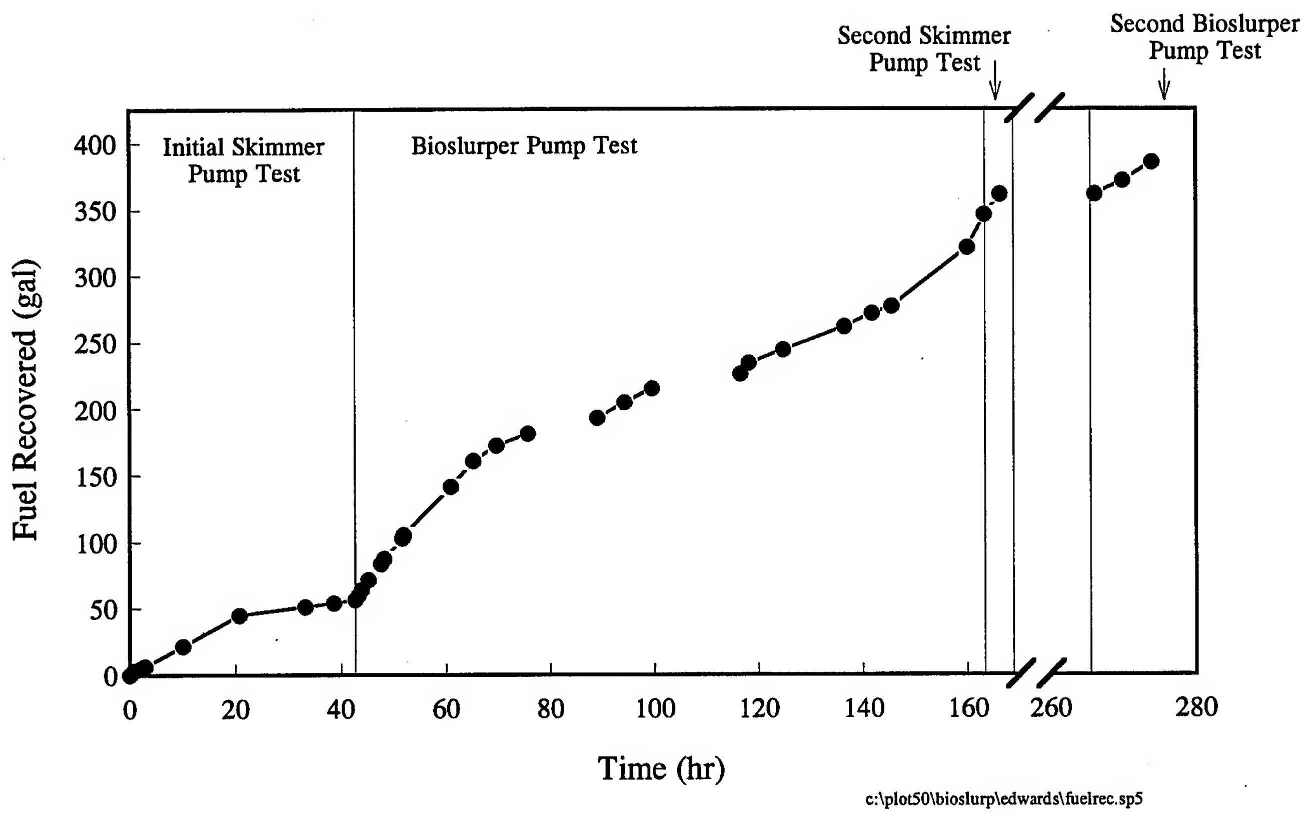


**Figure 5.** **LNAPL Recovery Versus Time During Each Pump Test (breaks in curve represent periods where bioslurper pump shut down)**

for LNAPL and 580 gallons/day for groundwater (Table 6). The LNAPL recovery rate versus time is shown in Figure 6. The vacuum-exerted wellhead pressure on monitoring well 24-MW26 was kept relatively constant throughout the bioslurper pump test at approximately 6 inches of mercury.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased significantly at all monitoring points (Table 7). These results correlate with the 43 ft radius of influence determined during the soil gas permeability test described in Section 4.5.1.

**Table 7. Oxygen Concentrations During the Bioslurper Pump Test at Site 24, Edwards AFB, CA**

| Monitoring Point | Oxygen Concentrations (%) Versus Time (hours) | | | |
|---|---|---|---|---|
| | 0 | 47 | 74 | 123 |
| MPA-10.0′ | 6.9 | 17.7 | 20.2 | 20.5 |
| MPA-15.0′ | 3.6 | 17.2 | 18.4 | 19.6 |
| MPA-20.0′ | 12.6 | 11.8 | 15.2 | 18.7 |
| MPB-10.0′ | 3.9 | 13.8 | 16.2 | 14.7 |
| MPB-15.0′ | 3.4 | 5.3 | 8.9 | 5.7 |
| MPB-20.0′ | 4.2 | 3.3 | 5.5 | 6.4 |
| MPC-5.0′ | NM | NM | 7.5 | 4.2 |
| MPC-10.0′ | 2.8 | 11.6 | 11.2 | 4.0 |
| MPC-15.0′ | 3.3 | 13.3 | 11.2 | 4.3 |
| MPC-20.0′ | NM | NM | NM | NM |

NM = Not measured. High moisture content did not allow for collection of soil gas samples.

### 4.3.3 Second Skimmer Pump Test

A total of 15 gallons of LNAPL was recovered during the second skimmer pump test, with a daily average recovery rate of 120 gallons/day (Table 6). No groundwater was recovered during this

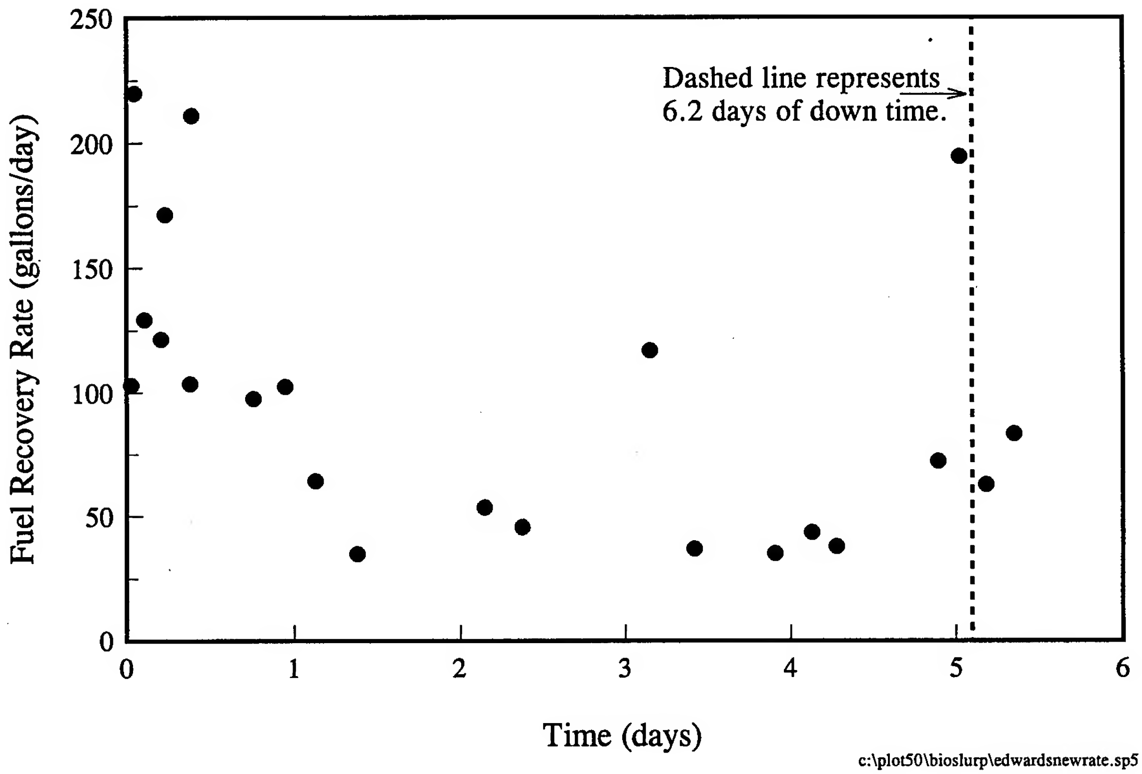


**Figure 6. LNAPL Recovery Rate Versus Time During the Bioslurper Pump Test**

pump test. These results demonstrate that operation of the bioslurper system in the skimmer mode was not as effective a means of free-product recovery as the bioslurper system at this site.

### 4.3.4 Second Bioslurper Pump Test

Totals of 24 gallons of LNAPL and 190 gallons of groundwater were recovered after the restart of the bioslurper pump test, with daily average recovery rates of 73 gallons/day for LNAPL and 570 gallons/day for groundwater (Table 6). Results indicate recovery rates similar to those obtained during the initial bioslurper pump test.

## 4.4 Extracted Groundwater, LNAPL, and Off-Gas Analyses

During the bioslurper pump test, groundwater samples were collected from the oil/water separator. In general, BTEX and TPH concentrations were relatively low, with an average TPH concentration of 15 mg/L and an average BTEX concentration of approximately 5 mg/L (Table 8). Benzene was detected in concentrations of approximately 0.70 mg/L.

Off-gas samples from the bioslurper system also were collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 9. Sample EAFB-A2 represents a sample collected prior to ICE treatment and samples EAFB-A1 and EAFB-A4 represent samples collected after treatment through the ICE. Given a vapor flow of 5 scfm from the bioslurper well and a vapor concentration before ICE treatment of approximately 26,000 ppmv TPH and 170 ppmv benzene, emissions without ICE treatment would have been approximately 76 lb/day of TPH and 0.25 lb/day of benzene. With the ICE in place, at a vapor discharge rate of 50 scfm and using an average concentration of 260 ppmv TPH and 8.6 ppmv benzene, approximately 7.6 lb/day of TPH and 0.13 lb/day benzene was emitted to the air during the bioslurper pump test. The treatment efficiency of the ICE unit was approximately 90% for TPH and 50% for BTEX.

The composition of LNAPL is shown in Tables 10 and 11 in terms of BTEX concentrations and distribution of C-range compounds, respectively. The distribution of C-range compounds is shown graphically in Figure 7.

**Table 8. BTEX and TPH Concentrations in Extracted Groundwater During the Bioslurper Pump Test at Site 24, Edwards AFB, CA**

| Parameter | Concentration (mg/L) | | | | | |
|---|---|---|---|---|---|---|
| | EAFB-W1 | EAFB-W2 | EAFB-W3 | EAFB-W4 | EAFB-W5 | EAFB-W6 |
| TPH (diesel) | 11 | 11 | 10 | 10 | 10 | 11 |
| TPH (gasoline) | 13 | 17 | 15 | 16 | 14 | 16 |
| Benzene | 0.69 | 0.69 | 0.70 | 0.70 | 0.70 | 0.69 |
| Toluene | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.9 |
| Ethylbenzene | 0.37 | 0.37 | 0.36 | 0.35 | 0.33 | 0.38 |
| Total Xylenes | 2.1 | 2.1 | 2.0 | 1.9 | 2.0 | 2.0 |

**Table 9. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at Site 24, Edwards AFB, CA**

| Parameter | Concentration (ppmv) | | | | |
|---|---|---|---|---|---|
| | EAFB-A1 (after ICE) | EAFB-A2 (prior to ICE) | EAFB-A3 (ambient) | EAFB-A4 (after ICE) | EAFB-5 (ambient) |
| TPH as jet fuel | 1,800 | 26,000 | 1,300 | 260 | 0.58 |
| Benzene | 14 | 170 | 0.12 | 8.6 | <0.0020 |
| Toluene | 13 | 330 | 3.2 | 0.98 | <0.0020 |
| Ethylbenzene | 7.6 | 100 | 5.5 | <0.022 | <0.0020 |
| Xylenes | 32 | 420 | 26 | 0.11 | <0.0020 |

**Table 10. BTEX Concentrations in LNAPL from Site 24, Edwards AFB, CA**

| Compound | Concentrations (mg/kg) |
|---|---|
| Benzene | <130 |
| Toluene | 1,800 |
| Ethylbenzene | 1,500 |
| Total Xylenes | 8,200 |

**Table 11. C-Range Compounds in LNAPL from Site 24, Edwards AFB, CA**

| C-Range Compounds | Percentage of Total |
|---|---|
| <C9 | 14.0 |
| C10 | 14.4 |
| C11 | 15.9 |
| C12 | 16.1 |
| C13 | 14.1 |
| C14 | 10.1 |
| C15 | 6.1 |
| C16 | 3.4 |
| C17 | 5.9 |

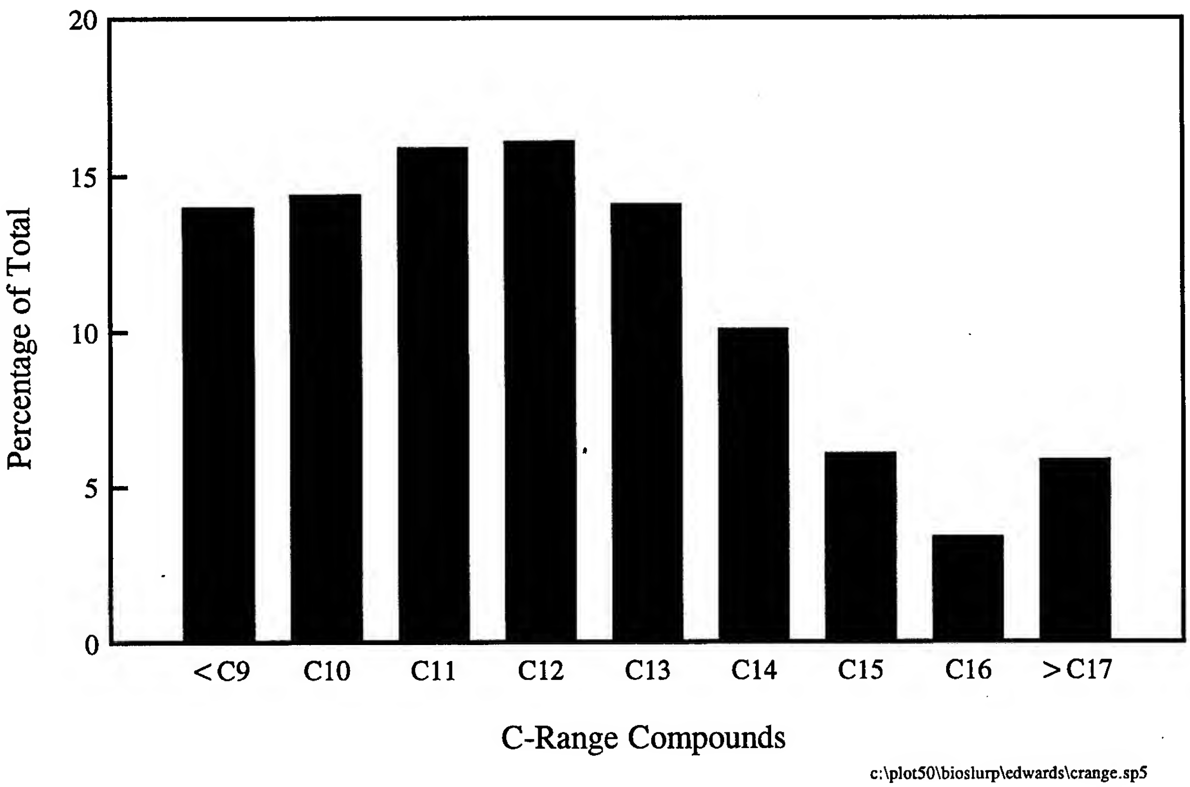


**Figure 7.** **Distribution of C-Range Compounds in Extracted LNAPL at Site 24, Edwards AFB, CA**

## 4.5 Bioventing Analyses

### 4.5.1 Soil Gas Permeability and Radius of Influence

The radius of influence is calculated by plotting the log of the pressure change at a specific monitoring point versus the distance from the extraction well. The radius of influence is then defined as the distance from the extraction well where 0.1 inch of $H_2O$ can be measured. Based on this definition, the radius of influence at this site is approximately 43 ft (Figure 8).

### 4.5.2 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 12. Oxygen depletion was relatively rapid, with oxygen utilization rates ranging from 0.026 to 1.7%$O_2$/hr. Biodegradation rates ranged from 0.42 to 28 mg/kg-day. The helium concentration was steady, indicating that leakage and diffusion were insignificant.

**Table 12. In Situ Respiration Test Results at Site 24, Edwards AFB, CA**

| Monitoring Point | Oxygen Utilization Rate (%/hr) | Biodegradation Rate (mg/kg-day) |
|---|---|---|
| MPA-10′ | 0.026 | 0.42 |
| MPA-15′ | 0.033 | 0.54 |
| MPA-20′ | 0.10 | 1.7 |
| MPB-10′ | 0.032 | 0.52 |
| MPB-15′ | 0.028 | 0.46 |
| MPB-20′ | 0.088 | 1.4 |
| MPC-10′ | 1.7 | 28 |
| MPC-15′ | 0.43 | 7.0 |
| MPC-20′ | 0.23 | 3.7 |

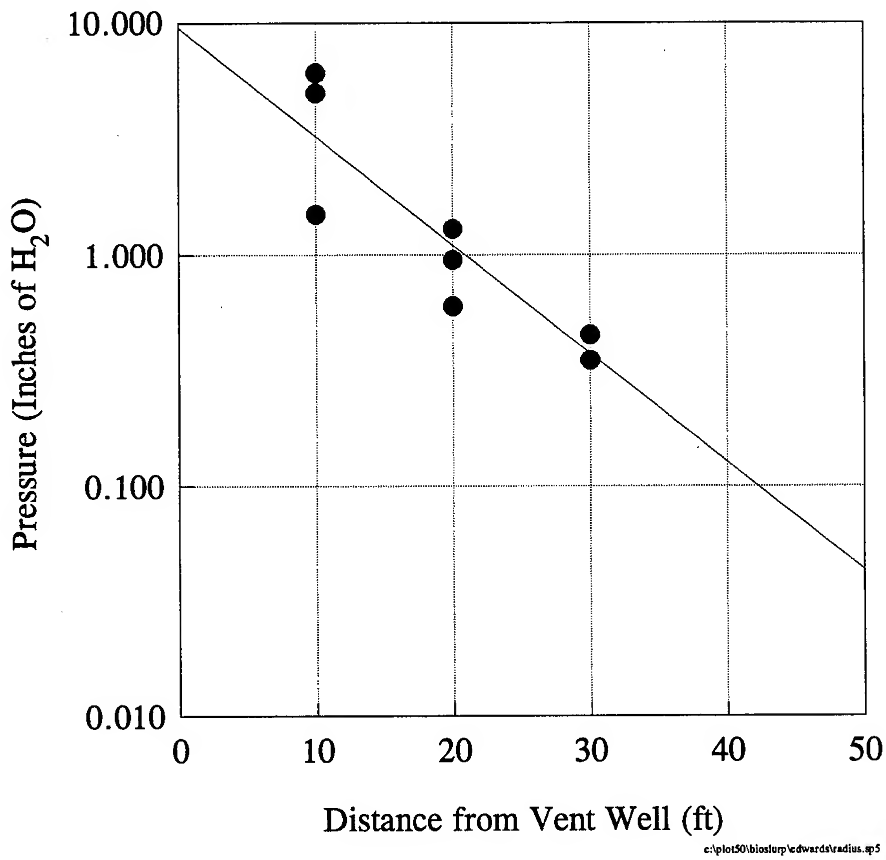


**Figure 8.** **Soil Gas Pressure Change as a Function of Distance During the Soil Gas Permeability Test**

## 5.0 DISCUSSION

The ICE was effective in providing electrical power to operate the liquid ring pump. The ICE also proved to be effective in reducing TPH emissions by 90% and benzene emissions by 50%. While the engine did provide adequate electrical power, there were operational problems associated with the ICE. The voltage regulator had to be replaced after 24 hours of operation and there were several equipment repairs that had to be made during the first weeks of operation (Appendix X). Continuous long-term operation of the ICE/generator will be necessary to fully evaluate the feasibility of using the ICE to provide safe, reliable, electrical power to ancillary equipment.

Results from the initial skimmer pump test indicated that skimmer pumping was not as effective as bioslurping at recovering LNAPL from this site. Free-product recovery rates decreased steadily during skimmer pumping, beginning at a rate of approximately 52 gallons/day during the initial skimmer pump test and decreasing to approximately 13 gallons/day by the end of the second skimmer pump test. Free-product recovery rates during the bioslurper pump test also decreased after the first day, but remained relatively stable after this time at approximately 50 gallons/day. The second skimmer pump test operated for such a short period of time that it is difficult to evaluate these results.

Groundwater recovery rates during the bioslurper pump test were high in comparison to rates during the skimmer pump tests. On average, groundwater was extracted at rates of 580 gallons/day during bioslurping and 8 gallons/day during skimming.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased significantly at all monitoring points. These results correlate with the 43 ft radius of influence determined during the soil gas permeability test.

Implementation of bioslurping at the Edwards AFB test site probably would facilitate enhanced recovery of LNAPL from the water table and simultaneous in situ biodegradation of hydrocarbons in the vadose zone via bioventing. Bioslurping will result in a vapor stream requiring treatment and the extraction of significant quantities of groundwater; however, the treatment options of utilizing an ICE for vapor treatment and discharging the groundwater for treatment by the Base make bioslurping a cost-effective alternative for long-term remediation.

# 6.0 REFERENCES

Battelle. 1995. *Test Plan and Technical Protocol for Bioslurping*, Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Rev. 2), Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc. for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

# APPENDIX A

# SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT EDWARDS AFB, CA

# SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT SITE 24, EDWARDS AFB, CALIFORNIA

## FINAL

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
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8001 ARNOLD DRIVE
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AND

EM
EDWARDS AFB, CALIFORNIA

12 SEPTEMBER 1995

# SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT EDWARDS AIR FORCE BASE, CALIFORNIA (A002)
CONTRACT NO. F41624-94-C-8012

FINAL

to

U.S. Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
8001 Arnold Drive
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for

Edwards AFB, CA
EM

September 12, 1995

by

Battelle
505 King Avenue
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**SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT EDWARDS AIR FORCE BASE, CALIFORNIA**

**FINAL**

**U.S. Air Force Center for Environmental Excellence**
**Technology Transfer Division**
**(AFCEE/ERT)**
**Brooks AFB, TX**

**September 12, 1995**

## 1.0 INTRODUCTION

The Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division is conducting a nationwide application of an innovative technology for free-product recovery and soil bioremediation. The technology tested in the Bioslurper Initiative is vacuum-enhanced free-product recovery/bioremediation (bioslurping). The field test and evaluation are intended to demonstrate the feasibility of bioslurping by measuring system performance in the field. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as a technology for recovering light, nonaqueous-phase liquids (LNAPLs) relative to conventional gravity-driven LNAPL recovery technologies. System performance parameters, mainly free-product recovery, will be determined at numerous sites. Field testing will be performed at many sites to determine the effects of different organic contaminant types and concentrations and different geologic conditions on bioslurping effectiveness.

Plans for the field test activities are presented in two documents. The first is the overall Test Plan and Technical Protocol for the entire program, titled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall Test Plan and Technical Protocol is supplemented by test plans specific to each site. The concise site-specific test plans communicate to base personnel site activities, operational parameters, and vapor and aqueous discharge rates for compliance with regulatory requirements specific to the base.

The overall Test Plan and Technical Protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of site-specific test plan preparation and to ensure consistent data collection across all test sites. The field program requires installation and operation of the bioslurping system supported by a wide variety of site characterization, performance monitoring, and chemical analysis activities. The basic methods to be applied from site to site do not change. Preparation and review of the overall Test Plan and Technical Protocol have resulted in efficient documentation and review of the basic approach to the test program. Peer and regulatory review were performed for the overall Test Plan and Technical Protocol to ensure the credibility of the overall program.

This report is the Site-Specific Test Plan for application of bioslurping at Edwards Air Force Base (AFB), California. It was prepared based on site-specific information received by Battelle from Edwards AFB and other pertinent site-specific information to support the generic Test Plan and Technical Protocol.

Site-specific information for Edwards AFB included data for five sites along the Main Base Flight Line: Sites 11, 16, 18, 21, and 24. An initial review of the data indicated that Site 24 will be the most likely candidate for the bioslurper pilot test. Specifically, Well 24-MW26 appeared to be the best candidate. If Well 24-MW26 is unsuitable for testing, an additional well may have to be installed.

## 2.0 SITE DESCRIPTION

Site 24 is located west of Wolfe Avenue and northeast of Building 3804 (Figure 1). Nine underground storage tanks (USTs) and a drainage ditch are located at Site 24. The four USTs (Tanks M027 through M030) located east of Building 3804 in Area 3807 contained AVGAS (Tank M029) and jet fuel (Tanks M027, M028, and M030). Tanks M028 and M030 failed leak tests in 1990 and are believed to be the source of contamination in the area. A fifth tank (Tank M089), located near Tanks M027 through M030, leaked approximately one-half of its contents in 1985; however, the tank contents are unknown.

Site soils consist primarily of fine- to medium-grained silty sands with a discontinuous clay layer above the weathered bedrock. Depth to weathered bedrock is approximately 10 ft. Groundwater occurs at a depth of approximately 22 ft.

Free product has been detected consistently in Well 24-MW26. Depths to free product have ranged from 0.07 to 5 ft. Total petroleum hydrocarbons (TPH) have been detected in both soil and groundwater samples. Benzene, toluene, ethylbenzene, and xylenes (BTEX) have been detected in groundwater.

## 3.0 PROJECT ACTIVITIES

The following field activities are planned for the bioslurper pilot test at Edwards AFB. Additional details about the activities are presented in the *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). As appropriate, specific sections in the generic Test Plan and Technical Protocol are referenced. Table 1 shows the schedule of activities for the Bioslurper Initiative at Edwards AFB.

### 3.1 Mobilization to the Site

After the Site-Specific Test Plan is approved, Battelle staff will mobilize equipment. Some of the equipment will be shipped via air express to Edwards AFB prior to staff arrival. The Base Point of Contact (POC) will be asked in advance to find a suitable holding facility to receive the bioslurper pilot test equipment so that it will be easily accessible to the Battelle staff when they arrive with the remainder of the equipment. The exact mobilization date will be confirmed with the Base POC as far in advance of fieldwork as is possible. The Battelle POC will provide the Edwards AFB POC with information on each Battelle employee who will be on site. Battelle personnel will be mobilized to the site after it has been confirmed that the shipped equipment has been received by Edwards AFB.

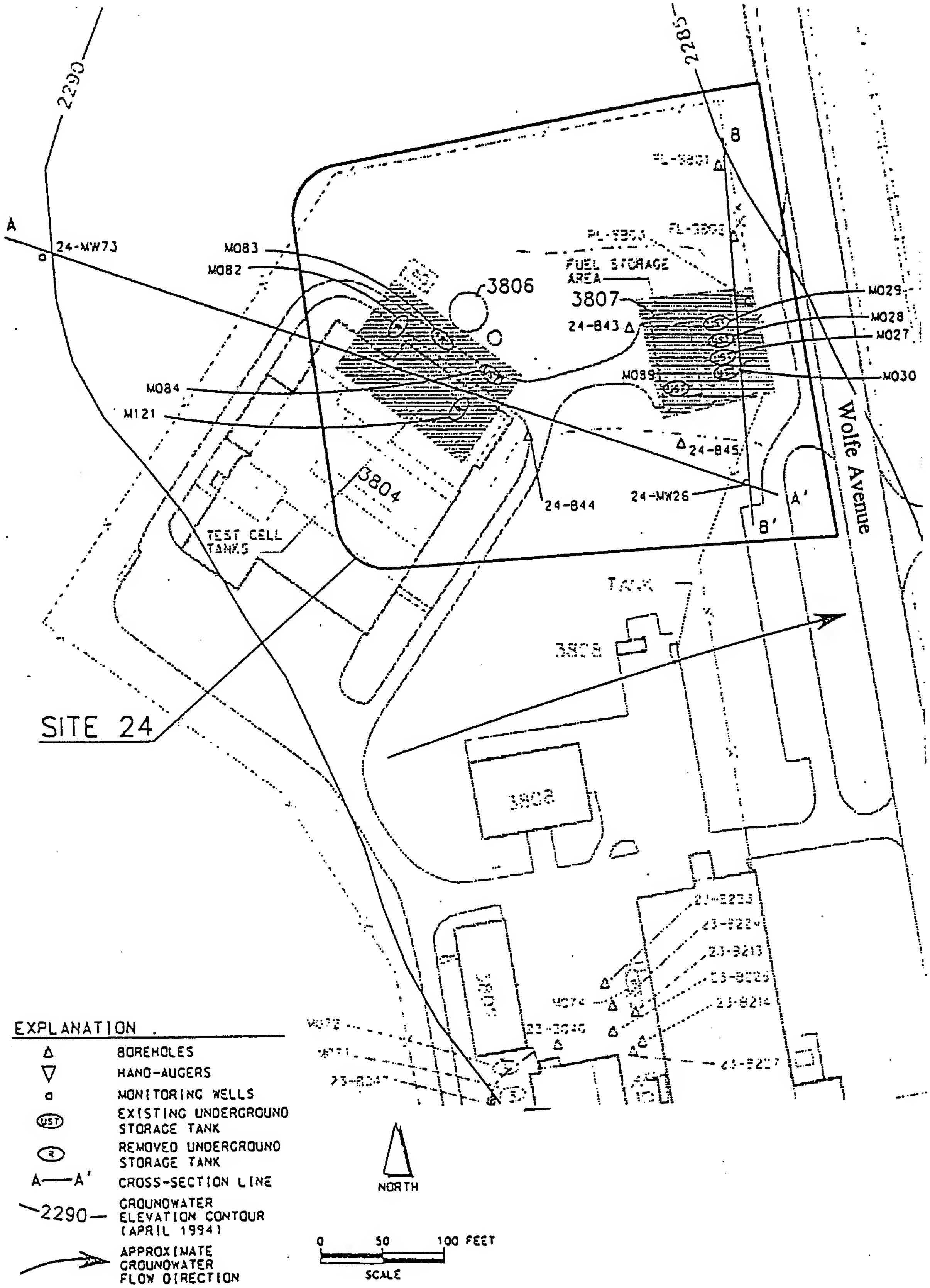


**Figure 1.** Schematic Diagram Showing Monitoring Well Locations at Site 24, Edwards AFB, California

**Table 1. Schedule of Bioslurper Test Activities**

| Pilot Test Activity | Schedule |
|---|---|
| Mobilization | Day 1-2 |
| Site Characterization | Day 2-3 |
| Baildown Tests and Product/Groundwater Interface Monitoring | |
| Soil Gas Survey (Limited) | |
| Slug Tests | |
| Monitoring Point (MP) Installation (3 MPs) | |
| Soil Sampling (TPH, BTEX, physical characteristics) | |
| System Installation | Day 2-3 |
| Test Startup | Day 3 |
| Skimmer Test (2 days) | Day 3-4 |
| Bioslurper Vacuum Extraction (4 days) | Day 6-9 |
| Soil Gas Permeability Testing | Day 6 |
| Skimmer Test (1 day) | Day 10 |
| In Situ Respiration Test — Air/Helium Injection | Day 10 |
| In Situ Respiration Test — Monitoring | Day 11-16 |
| Drawdown Pump Test (2 days) | Day 11-12 |
| Demobilization/Mobilization | Day 13-14 |

## 3.2 Site Characterization Tests

### 3.2.1 Baildown Tests

The baildown test is the primary test used to select the bioslurper test well. Baildown tests will be performed at wells that contain measurable thicknesses of LNAPL to estimate the LNAPL recovery potential at those particular wells. A baildown test will be conducted on Well 24-MW26. A sample of the extracted LNAPL will be collected at this time for analyses of boiling point composition and BTEX concentration. Detailed procedures for the baildown test are provided in Section 5.6 of the generic Test Plan and Technical Protocol.

### 3.2.2 Soil Gas Survey (Limited)

A small-scale soil gas survey will be conducted to identify the best location for installation of the soil gas monitoring points. The soil gas survey will be conducted in areas where historical site data indicate the highest contamination levels. Soil gas monitoring points will be located in areas that exhibit the following characteristics:

1. Relatively high TPH concentrations (10,000 ppmv or greater).

2. Relatively low oxygen concentrations (between 0% and 2%).

3. Relatively high carbon dioxide concentrations (depending on soil type, between 2% and 10% or greater).

To obtain further information about the soil gas survey, consult Section 5.2 of the generic Test Plan and Technical Protocol.

### 3.2.3 Slug Tests

To determine the characteristics of the aquifer where the candidate bioslurper test well is located, slug tests will be performed on Well 24-MW73, which was installed as a background well. Slug tests will be performed using an in situ pressure transducer and a Hermit data logger to track pressure (water level) changes induced by a polyvinyl chloride capsule (slug) containing a known volume of water. The data collected during the slug test will be used to examine the ability of the aquifer to recharge with water at Site 24. Additional information about the slug test methods can be found in Section 5.7 of the overall Test Plan and Technical Protocol.

### 3.2.4 Monitoring Point Installation

Monitoring points will be installed to determine the radius of influence of the bioslurper system in the vadose zone. A general arrangement of the bioslurping well and monitoring points is shown in Figure 2.

Upon conclusion of the initial soil gas survey and baildown tests, at least three soil gas monitoring points will be installed to measure soil gas changes that occur during bioslurper operation. These monitoring points should be located in highly contaminated soils within the free-phase plume and should be positioned to allow detailed monitoring of the in situ changes in soil gas composition caused

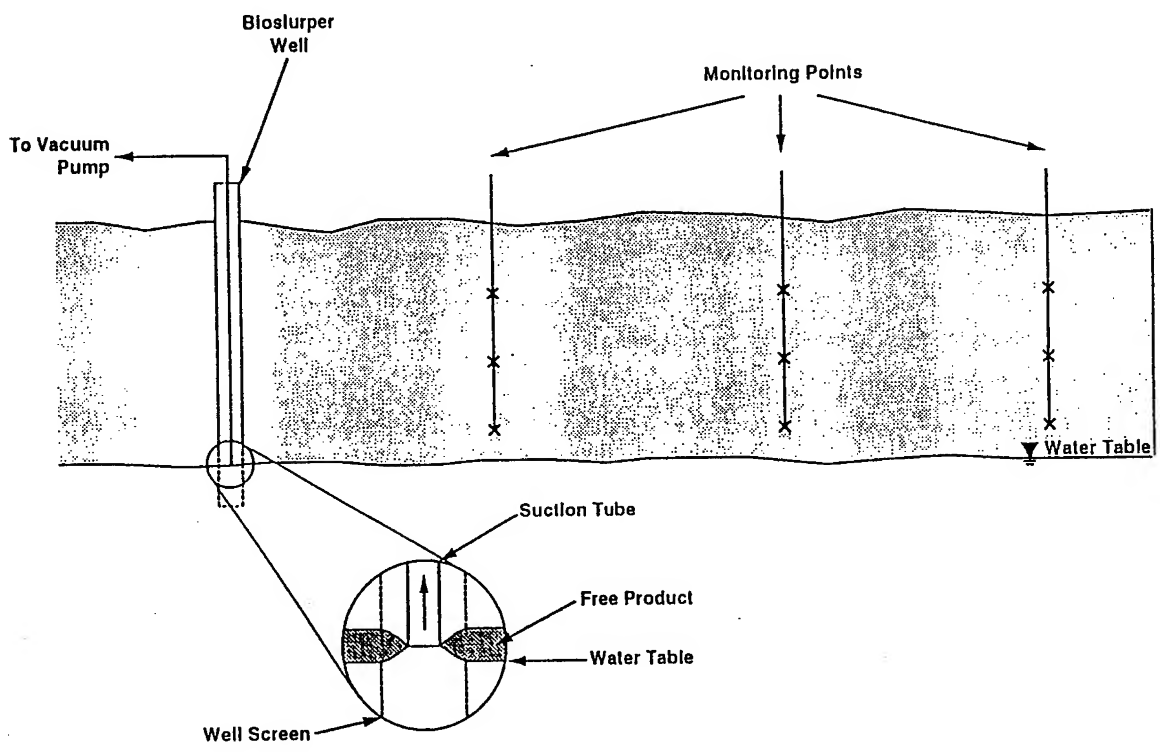


Figure 2. General Bioslurper Well and Monitoring Point Arrangement

by the bioslurper system. A schematic diagram of a typical soil gas monitoring point is shown in Figure 3. Information on monitoring point installation appears in Section 4.2.1 of the generic Test Plan and Technical Protocol.

### 3.2.5 Soil Sampling

Soil samples will be collected to determine the physical and chemical composition of the soil near the site chosen for the bioslurper test. Soil samples will be collected from the boreholes advanced for monitoring point installation at two or three locations at the site. Generally, samples will be collected from the capillary fringe over the free product.

Soil samples from each boring will be analyzed for BTEX, bulk density, moisture content, particle-size distribution, porosity, and TPH. Section 5.5.1 of the generic Test Plan and Technical Protocol contains information on the field measurements and sample collection procedures for soil sampling.

## 3.3 Bioslurper System Installation and Operation

### 3.3.1 System Setup

Upon completion of the preliminary site characterization tests, the previously shipped equipment will be mobilized from the holding facility to the test site, and the bioslurper system will be assembled. Figure 4 shows a flow diagram of the bioslurper process. Figure 5 is a schematic diagram of a typical bioslurper extraction well that will be configured using an existing monitoring well at Edwards AFB. An internal combustion engine (ICE), manufactured by RSI, Inc., will be used to treat the off-gas of the bioslurper system. The ICE also will supply the power necessary to run the bioslurper system generator.

Before the LNAPL recovery tests are initiated, all relevant baseline field data will be collected and recorded. These data will include soil gas concentrations, initial soil gas pressures, the depth to groundwater, and the LNAPL thickness. Ambient soil and all atmospheric conditions (e.g., temperature, humidity, barometric pressure) also will be recorded. All emergency equipment (i.e., emergency shutoff switches and fire extinguishers) will be installed and checked for proper operation at this time.

A clear, level 20- by 10-ft area near the well will be identified to station the equipment required for bioslurper system operation. For more information on bioslurper system installation, consult Section 6.0 of the generic Test Plan and Technical Protocol.

### 3.3.2 System Shakedown

A brief startup test will be conducted to ensure that the system is constructed properly and operates safely. All system components will be checked for problems and/or malfunctions. A checklist will be provided to document the system shakedown.

### 3.3.3 System Startup and Test Operations

After installation is complete and the bioslurper system is confirmed to be operating properly, the LNAPL recovery tests will be started. The Bioslurper Initiative has been designed to evaluate the

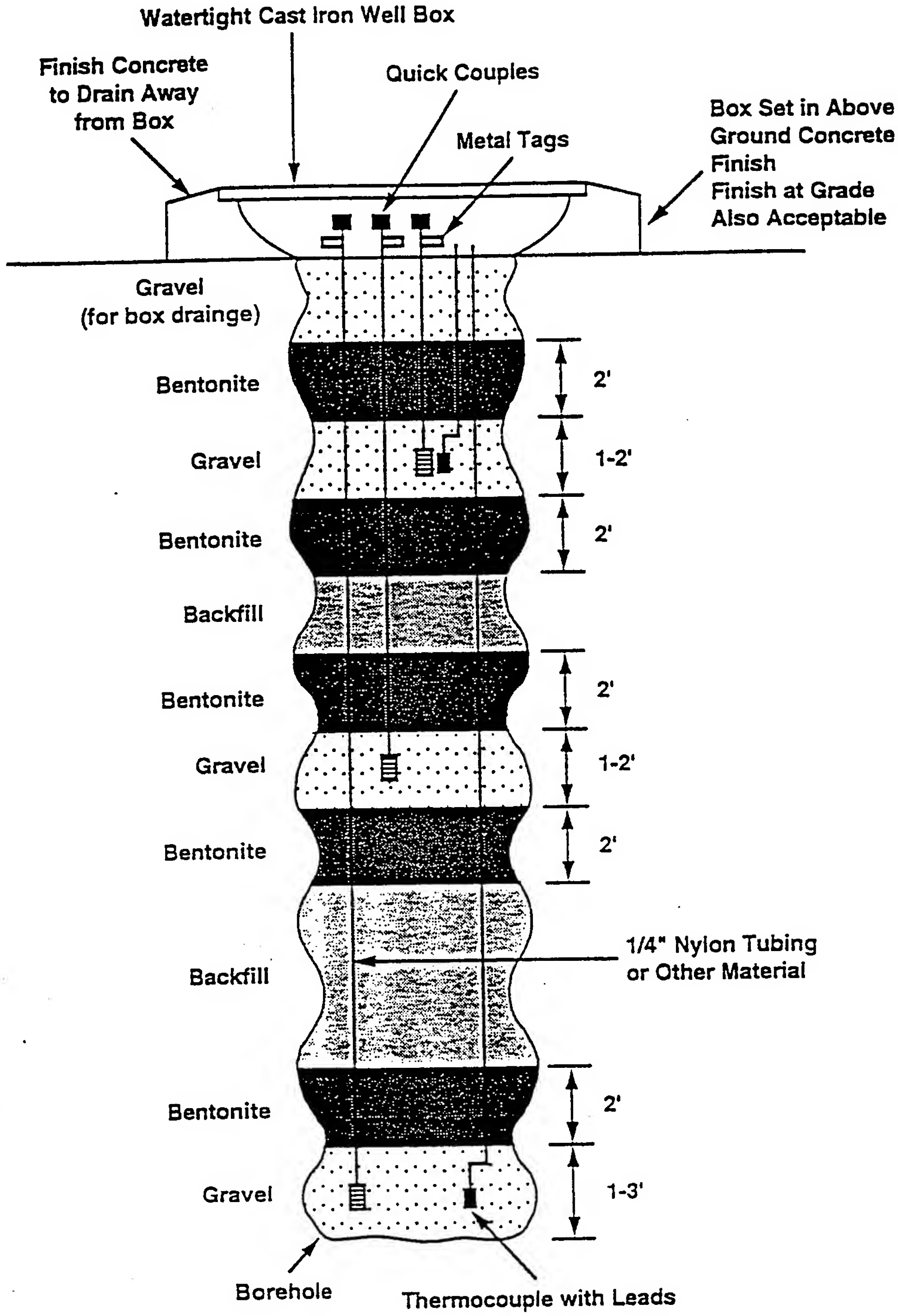


Figure 3. Schematic Diagram of a Typical Soil Gas Monitoring Point

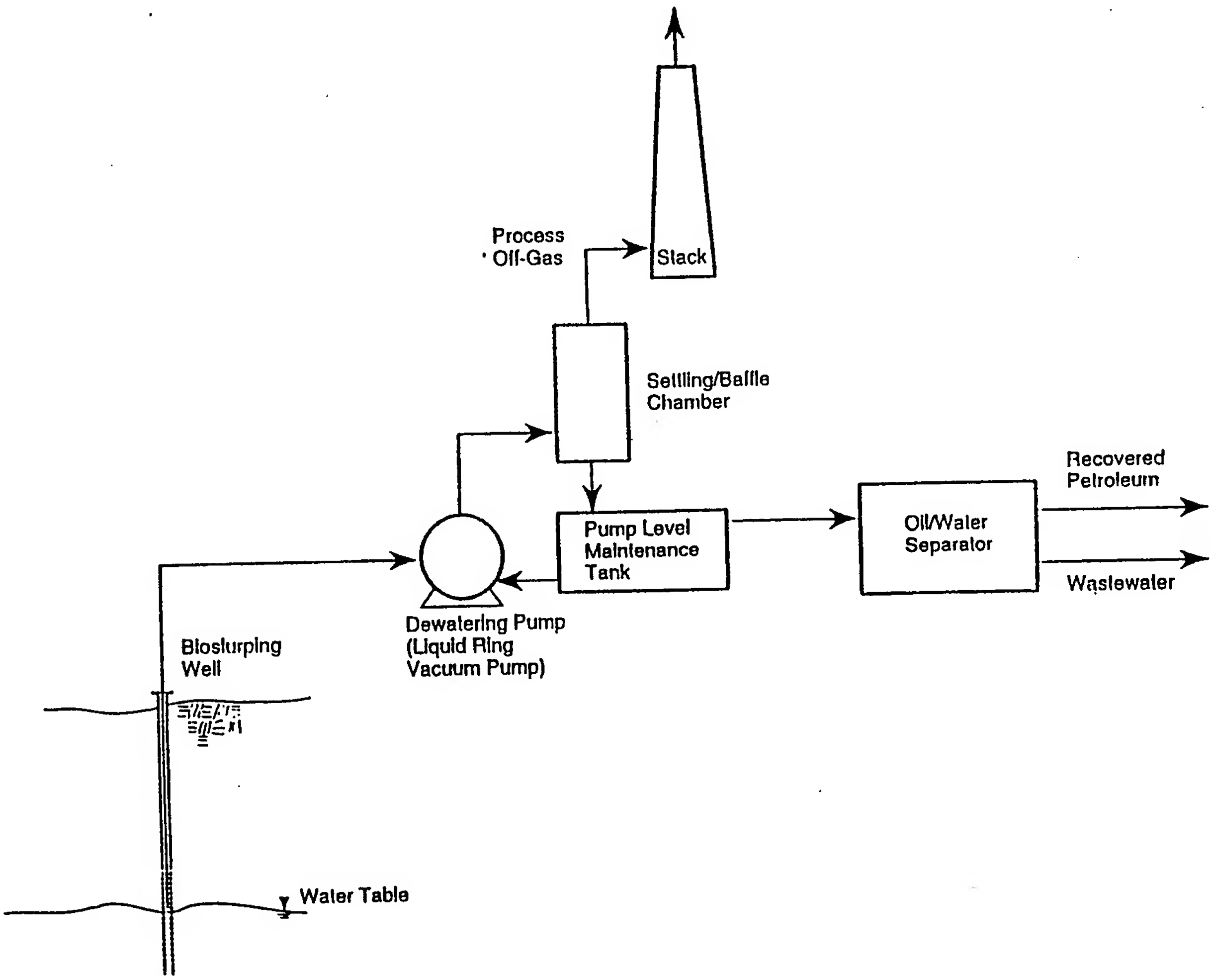


Figure 4. Bioslurper Process Flow

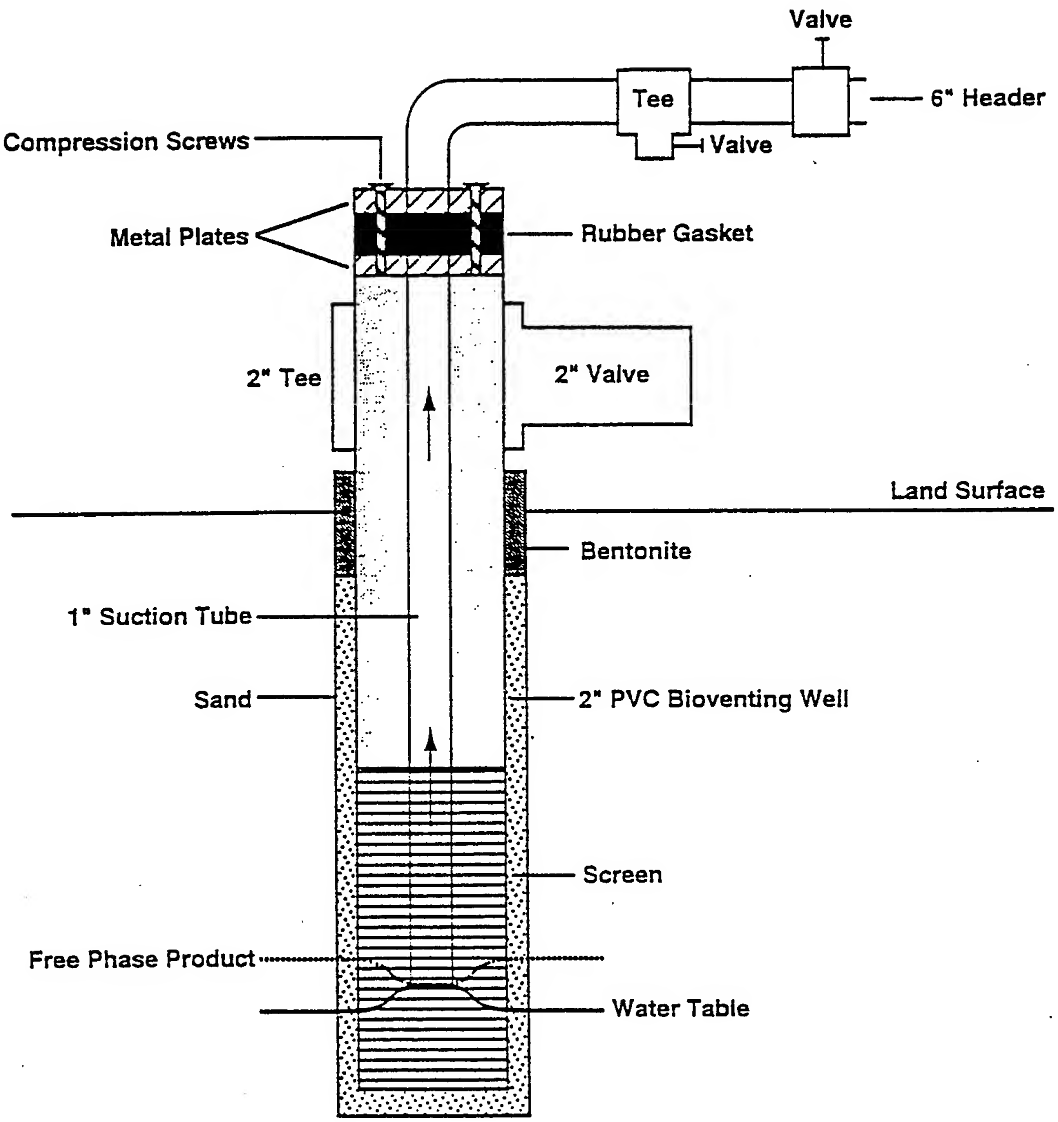


Figure 5. Schematic Diagram of a Typical Bioslurper Well

effectiveness of bioslurping as an LNAPL recovery technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative Test Plan and Technical Protocol includes three separate LNAPL recovery tests: (1) a skimmer simulation test, (2) a vacuum-assisted bioslurper test, and (3) a groundwater drawdown LNAPL recovery test. The three recovery tests are described in detail in Section 7.3 of the generic Test Plan and Technical Protocol.

The bioslurper system operating parameters that will be measured during operation are vapor discharge, aqueous effluent, LNAPL recovery volume rates, vapor discharge volume rates, and groundwater discharge volume rates. Vapor monitoring will consist of intermittent monitoring of TPH using hand-held instruments supplemented by two samples collected for detailed laboratory analysis. Two samples of aqueous effluent will be collected for analysis of BTEX and TPH. The recovered LNAPL volume will be recorded using an in-line flow-totalizing meter. The off-gas discharge volume will be measured using a calibrated pitot tube, and the groundwater discharge volume will be recorded using an in-line flow-totalizing meter. Section 8.0 of the generic Test Plan and Technical Protocol describes process monitoring of the bioslurper system.

### 3.3.4 Soil Gas Permeability Tests

A soil gas permeability test will be conducted concurrently with startup of the bioslurper. Soil gas permeability data will support the process of estimating the bioslurper system's vadose zone radius of influence. Soil gas permeability results also will aid in determining the number of wells required if it is decided to treat the site with a large-scale bioslurper system. The soil gas permeability test method is described in Section 5.7 of the generic Test Plan and Technical Protocol.

### 3.3.5 LNAPL and Water Level Monitoring

A well adjacent to the bioslurper pilot test extraction well will be used to monitor LNAPL and water level fluctuations in the site aquifer. The top of the well will be sealed with a Teflon™ seal, which will allow an oil/water interface probe to be used to measure LNAPL and water levels in the well without breaking the subsurface vacuum. Level measurements will be taken intermittently during the bioslurper pilot test.

### 3.3.6 In Situ Respiration Tests

An in situ respiration test will be conducted after the bioslurper operating tests are completed. The in situ respiration testing will involve injection of air and helium into selected soil gas monitoring points followed by monitoring changes in concentrations of oxygen, carbon dioxide, TPH, and helium in soil gas at the injection points. Measurement of the soil gas composition typically will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours for about 2 days. The timing of the tests will be adjusted based on the oxygen-use rate. If oxygen depletion occurs rapidly, more frequent monitoring will be conducted. If oxygen depletion is slow, less frequent readings will be acceptable. The oxygen utilization rate will be used to estimate the biodegradation rate at the site. Further information on the procedures and data collection for in situ respiration testing is given in Section 5.8 of the generic Test Plan and Technical Protocol.

### 3.3.7 Extended Testing

The AFCEE/ERT will extend the operation of the bioslurper system for up to 6 months if LNAPL recovery rates are promising and long-term vapor and aqueous discharge requirements have been established. When the extended testing is to be performed, the Air Force will need to provide electrical power for long-term operation of the bioslurper pump. Disposition of all generated wastes and routine operation and maintenance of the system will be the Air Force's responsibility. Battelle will provide technical support during the extended testing operation. During the extended testing, it is intended to place the bioslurper equipment within the Jet Engine Maintenance Yard (JEMY), which is a secured area.

## 3.4 Demobilization

Once all necessary tests have been completed at the Edwards AFB site, the equipment will be disassembled by Battelle staff and moved back to the holding facility, where it will remain until its next destination is determined. Battelle staff will receive this information and will be responsible for shipment of the equipment to the next site before they leave Edwards AFB.

# 4.0 BIOSLURPER SYSTEM DISCHARGE

## 4.1 Vapor Discharge Disposition

Bioslurper vapor discharge will be treated using an ICE treatment system. Due to the federal facility status of Edwards AFB, no official permit needs to be issued for operation of the ICE. However, substantive requirements must be met. The ICE is capable of meeting these substantive requirements, as shown in the Performance and Cost Evaluation of the ICE provided in Appendix B. Destruction efficiencies of the ICE unit are expected to exceed 95%. Because the effectiveness of the ICE treatment has been demonstrated and on-site monitoring of vapor discharge from the ICE unit is planned, no unacceptable health risks to site staff or base personnel will result from the bioslurper pilot test operations.

Based on previous experience, it is estimated that approximately 46 lb/day and <1.0 lb/day of untreated TPH and benzene contamination, respectively, will enter the ICE. This value is based on the average TPH discharge level at three bioslurper test sites (Johnston Atoll, Travis AFB, and Wright-Patterson AFB) that are contaminated with jet fuel, the type of fuel found at Site 24. The actual value of untreated vapor entering the ICE will vary depending on the TPH concentration of the site soil gas and the permeability of the site soils. Vapor discharges at six previous bioslurper test sites are shown in Table 2. The relatively high TPH discharge level at Travis AFB is due partially to the high extraction rate. This extraction rate is close to the maximum rate (25 scfm) that the 3-hp bioslurper pump can achieve and should be much lower at Edwards AFB where the soil is less permeable.

To ensure safe operation and regulatory compliance of the bioslurper system, influent and effluent vapor discharge samples (TPH, $O_2$, and $CO_2$) will be collected periodically throughout the bioslurper pilot test, and field soil gas screening instruments will be used to monitor vapor discharge concentration variability. The volume of vapor discharge will be monitored daily using air flow instruments. If state regulatory requirements will not permit the expected amount of organic vapor

Table 2. Benzene and TPH Discharge Levels at Previous Bioslurper Test Sites

| Site Location | Fuel Type | Extraction Rate (scfm) | Benzene (ppmv) | TPH (ppmv) | Benzene Discharge (lb/day) | TPH Discharge (lb/day) |
|---|---|---|---|---|---|---|
| Andrews AFB | No. 2 Fuel Oil | 8.0 | 16 | 2,000 | 0.0010 | 0.20 |
| Site 1, Bolling AFB | No. 2 Fuel Oil | 4.0 | 0.20 | 153 | 0.00030 | 0.0090 |
| Site 2, Bolling AFB | Gasoline | 21 | 370 | 70,000 | 2.3 | 470 |
| Johnston Atoll | Jet Fuel | 10 | 0.60 | 975 | 0.0017 | 5.7 |
| Travis AFB | Jet Fuel | 20 | 100 | 10,800 | 0.58 | 130 |
| Wright-Patterson AFB | Jet Fuel | 3 | ND | 595 | 0 | 1.0 |

ND = Not detected.

discharge to the atmosphere or will not allow the short-term use of an ICE, the Base POC should inform AFCEE and Battelle so that alternative plans can be made prior to mobilization to the site. Table 3 presents information typically required to complete an air release registration form.

### 4.2 Aqueous Influent/Effluent Disposition

The flowrate of groundwater pumped by the bioslurper will be less than 5 gpm. However, it may be necessary in California to obtain a groundwater pumping waiver or registration permit. If one is required, the Base POC will inform Battelle of the necessary steps for obtaining the waiver or permit.

Operation of the bioslurper system will generate an aqueous waste discharge that will be passed through an oil/water separator. For short-term pilot test operation, aqueous effluent will be pumped into on-site Baker tanks located in the JEMY. The Base will be responsible for coordinating removal and transport of the aqueous effluent from the Baker tanks to the Base holding facility.

### 4.3 Disposition of Recovered Free Product

The bioslurper system will recover free-phase product from the pilot tests performed at Edwards AFB. Free product recovered by the bioslurping tests will be turned over to the Base for disposal and/or recycling. The volume of free product recovered from the Base will not be known until the tests have been performed. The maximum recovery rate for this system is 5 gpm, but the actual rate of LNAPL recovery likely will be much lower.

**Table 3. Air Release Summary Information**

| Data Item | Air Release Information |
|---|---|
| Contractor Point of Contact | Jeff Kittel, (614) 424-6122 |
| Contractor address | Battelle, 505 King Avenue, Columbus, OH 43201 |
| Estimated total quantity of petroleum product to be recovered | TBD |
| Description of petroleum product to be recovered | JP-4 jet fuel |
| Planned date of test start | TBD |
| Test duration | 9 days (active pumping) |
| Maximum total quantity of VOC release | ~46 lb/day TPH, <1.0 lb/day benzene |
| Expected total of VOC release from ICE unit | ~2 lb/day TPH |
| Stack height above ground level | 10 ft |

## 5.0 SCHEDULE

The schedule for the bioslurper fieldwork at Edwards AFB will depend on approval of the Site-Specific Test Plan. Battelle will determine a definitive schedule as soon as possible after approval is received. Battelle will have two to three staff members on site for approximately 2 weeks to conduct all necessary pilot testing. At the conclusion of the field testing at Edwards AFB, Battelle staff will return their Base passes and will remove all bioslurper field testing equipment from the Base before they leave the site.

## 6.0 PROJECT SUPPORT ROLES

This section outlines some of the major functions of personnel from Battelle, Edwards AFB, and AFCEE during the bioslurper field test.

### 6.1 Battelle Activities

The obligations of Battelle in the Bioslurper Initiative at Edwards AFB will be to supply staff and equipment necessary to perform all the tests on the bioslurper system. Battelle also will provide technical support in the areas of water and vapor discharge permitting, digging permits, staff support during the extended testing period, and any other technical areas that need to be addressed.

### 6.2 Edwards AFB Support Activities

To support the necessary field tests at Edwards AFB, the Base must be able to provide the following:

1. Any digging permits and utility clearances that need to be obtained prior to the initiation of the fieldwork. Any underground utilities should be clearly marked to reduce the chance of utility damage and/or personal injury during soil gas probe and possible well installation. Battelle will not begin field operations without these clearances and permits.

2. The Air Force will be responsible for obtaining Base and site clearances for the Battelle staff that will be working at the Base. The Base POC will be furnished with all necessary information on each staff member at least 1 week prior to field startup.

3. The Air Force must provide access to the on-site Baker tanks located in the JEMY for discharge of aqueous effluent. The Base will be responsible for coordinating removal and transport of the aqueous effluent from the Baker tanks to the Base holding facility.

4. Regulatory approval, if required, must be obtained by the Base POC prior to startup of the bioslurper pilot test. As stated previously, it is likely that a waiver exclusion will be required to operate the ICE. Aqueous and vapor discharge requirements for long-term operation must be identified before long-term bioslurper testing is begun. The Base POC will obtain all necessary Base permits prior to mobilization to the site. Battelle will provide technical assistance in preparing regulatory approval documents.

5. The Base will be responsible for the disposition of all waste generated from the pilot testing. Such waste includes any soil cuttings generated from drilling, and all aqueous wastestreams produced from the bioslurper tests. All free product recovered from the bioslurper operation will be disposed of or recycled by the Base. Battelle will provide technical assistance in disposing of the waste generated from the bioslurper pilot test.

6. Before field activities begin, the Health and Safety Plan will be finalized with information provided by the Base POC. Table 4 is a checklist for the information required to complete the Health and Safety Plan. All emergency information will be obtained by the Site Health and Safety office before operations begin.

### 6.3 AFCEE Activities

The AFCEE POC will act as a liaison between Battelle and Edwards AFB staff. The AFCEE POC will ensure that all necessary permits are obtained and that space required to house the bioslurper field equipment is found.

The following is a listing of Battelle, AFCEE, and Edwards AFB staff who can be contacted in case of emergency and/or if technical support is required during the bioslurper field initiative tests at Edwards AFB.

**Table 4. Health and Safety Information Checklist**

| Emergency Contacts | Name | Telephone Number |
| --- | --- | --- |
| Hospital Emergency Room: | Emergency Room/ Edwards AFB | 911/(805) 277-2331 |
| Point of Contact: | Ed Fletcher/ AFFTC/SEG | (805) 277-8565 |
| Fire Department: | Local | (805) 277-4540 |
| Emergency Unit (Ambulance): | Flight Medicine | (805) 277-2575 |
| Security: | Base | (805) 277-2000 |
| Explosives Unit: | | |
| Community Emergency Response Coordinator: | Military Public Health | (805) 277-4238 |
| Other: | | |
| **Program Contacts:** Notify in case of emergency. | | |
| AFCEE | Patrick Haas | (210) 536-4314 |
| Air Force Edwards: | David Steckel | (805) 277-1416 |
| Battelle: | Jeff Kittel | (614) 424-6122 |
| Other: | Eric Drescher | (614) 424-3088 |

**Emergency Routes**

Hospital

Other: See Map to Hospital in Appendix C

| | | |
|---|---|---|
| Battelle POCs | Jeff Kittel | (614) 424-6122 |
| | Eric Drescher | (614) 424-3088 |
| AFCEE POC | Patrick Haas | (210) 536-4314 |
| Edwards AFB POC | David Steckel | (805) 277-1416 |
| Facility Chief of JEMY | Vince Haili | (805) 277-2489 |
| On-Site JEMY Facility Manager | Jeff Larve | (805) 277-2489 |
| Regulatory POCs | | |
| Air: | Tom Paxson | (805) 861-2593 |
| Water: | | |

# APPENDIX A

## FREE PRODUCT THICKNESSES AT THE MAIN BASE FLIGHT LINE SITES, EDWARDS AFB, CA

GROUNDWATER ELEVATIONS AND PRODUCT THICKN
EAFB MAIN BASE FLIGHT LINE SITE 16 (April 1993 thru

| Well No. | MP Elev (FT MSL) | April 1994 DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
|---|---|---|---|---|---|---|
| 16-01 | 2300.63 | | | | | |
| 16-02 | 2296.83 | 10.82 | | 0.00 | 2286.01 | 2286.01 |
| 16-03 | 2294.52 | 13.85 | | 0.00 | 2280.67 | 2280.67 |
| 16-04 | 2297.20 | 11.92 | | 0.00 | 2285.28 | 2285.28 |
| 16-06 | 2297.71 | 14.39 | 13.82 | 0.57 | 2283.32 | 2283.75 |
| 16-07 | 2296.28 | 6.56 | | 0.00 | 2289.72 | 2289.72 |
| 16-08 | 2298.00 | 8.07 | | 0.00 | 2289.93 | 2289.93 |
| 16-09 | 2293.66 | | | | | |
| 16-10 | 2294.59 | 5.33 | | 0.00 | 2289.26 | 2289.26 |
| 16-11 | 2294.77 | 5.08 | | 0.00 | 2289.69 | 2289.69 |
| 16-12 | 2296.39 | 9.78 | | 0.00 | 2286.61 | 2286.61 |
| 16-14 | 2297.22 | 15.09 | 14.29 | 0.80 | 2282.13 | 2282.74 |
| 16-15 | 2297.88 | 13.00 | | 0.00 | 2284.88 | 2284.88 |
| 16-16 | 2294.70 | 5.16 | | 0.00 | 2289.54 | 2289.54 |
| 16-17 | 2298.04 | 8.87 | | 0.00 | 2289.17 | 2289.17 |
| 16-18 | 2287.91 | 11.55 | | 0.00 | 2276.36 | 2276.36 |
| 16-22 | 2295.65 | 8.32 | | 0.00 | 2287.33 | 2287.33 |
| 16-23 | 2295.63 | 10.91 | | 0.00 | 2284.72 | 2284.72 |
| 16-24 | 2293.14 | 15.40 | | 0.00 | 2277.74 | 2277.74 |
| 16-25 | 2285.67 | 11.40 | | 0.00 | 2274.27 | 2274.27 |
| 16-26 | 2285.38 | 10.26 | 10.18 | 0.08 | 2275.12 | 2275.18 |
| 16-27 | 2284.29 | 13.32 | | 0.00 | 2270.97 | 2270.97 |
| 16-28 | 2285.39 | 12.64 | | 0.00 | 2272.75 | 2272.75 |
| 16-29 | 2284.95 | 11.16 | 10.82 | 0.34 | 2273.79 | 2274.05 |
| 16-30 | 2294.35 | 13.44 | | 0.00 | 2280.91 | 2280.91 |
| 16-32 | 2294.01 | 17.15 | | 0.00 | 2276.86 | 2276.86 |
| 16-MW29 | 2296.68 | 15.77 | | 0.00 | 2280.91 | 2280.91 |
| 16-MW35 | 2296.68 | 14.55 | | 0.00 | 2282.13 | 2282.13 |
| 16-MW36 | 2283.93 | 12.18 | | 0.00 | 2271.75 | 2271.75 |
| 16-MW44 | 2310.47 | 19.44 | | 0.00 | 2291.03 | 2291.03 |
| 16-MW45 | 2294.81 | 12.82 | | 0.00 | 2281.99 | 2281.99 |
| 16-MW46 | 2294.60 | 13.16 | | 0.00 | 2281.44 | 2281.44 |
| 16-MW48 | 2301.40 | 11.30 | | 0.00 | 2290.10 | 2290.10 |
| 16-MW49 | 2297.93 | 10.60 | | 0.00 | 2287.33 | 2287.33 |
| 16-MW50 | 2293.98 | 11.86 | | 0.00 | 2282.12 | 2282.12 |
| RW-01 | 2295.68 | 14.94 | | 0.00 | 2280.74 | 2280.74 |
| RW-02 | 2292.55 | 11.42 | | 0.00 | 2281.13 | 2281.13 |
| RW-03 | 2293.26 | 11.48 | | 0.00 | 2278.23 | 2278.23 |
| RW-04 | 2296.87 | 15.03 | | 0.00 | 2281.87 | 2281.87 |
| RW-05 | 2297.35 | 15.00 | | 0.00 | 2282.35 | 2282.35 |
| RW-06 | 2297.93 | 14.69 | 14.37 | 0.32 | 2283.24 | 2283.48 |
| RW-07 | 2297.26 | 13.37 | | 0.00 | 2283.89 | 2283.89 |
| RW-08 | 2297.05 | 12.25 | 12.15 | 0.10 | 2284.80 | 2284.88 |
| RW-09 | 2297.29 | 12.40 | | 0.00 | 2284.89 | 2284.89 |
| RW-10 | 2297.79 | 12.72 | | 0.00 | 2285.07 | 2285.07 |
| RW-11 | 2296.58 | 11.56 | | 0.00 | 2285.02 | 2285.02 |
| RW-12 | 2296.06 | 10.60 | | 0.00 | 2285.46 | 2285.46 |
| RW-13 | 2296.43 | 10.58 | | 0.00 | 2285.85 | 2285.85 |
| RW-14 | 2296.31 | 10.32 | | 0.00 | 2285.99 | 2285.99 |
| RW-15 | 2296.51 | 10.57 | | 0.00 | 2285.94 | 2285.94 |
| RW-16 | 2297.30 | 14.03 | | 0.00 | 2283.27 | 2283.27 |

DTW depth to water
DTF depth to fuel
MSL Mean sea level
MP Measuring point

GROUNDWATER ELEVATIONS AND PRODUCT THICKNESS
EAFB MAIN BASE FLIGHT LINE SITE 18 (April 1993 thru April 1994)

| | | APRIL 1993 | | | | | JULY 1993 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | MP Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
| 18-B01 | 2289.07 | 11.87 | | 0.00 | 2277.20 | 2277.20 | 11.84 | | 0.00 | 2277.23 | 2277.23 |
| 18-B03 | 2290.49 | 15.20 | | 0.00 | 2275.29 | 2275.29 | 15.17 | | 0.00 | 2275.32 | 2275.32 |
| 18-B04 | 2289.22 | 13.72 | | 0.00 | 2275.50 | 2275.50 | 13.84 | | 0.00 | 2275.38 | 2275.38 |
| 18-B06 | 2286.22 | 11.58 | | 0.00 | 2274.64 | 2274.64 | 12.20 | | 0.00 | 2274.02 | 2274.02 |
| 18-B07 | 2279.74 | 7.30 | 7.00 | 0.30 | 2272.44 | 2272.67 | 7.62 | 7.34 | 0.28 | 2272.12 | 2272.33 |
| 18-T01 | 2290.41 | 14.56 | | 0.00 | 2275.85 | 2275.85 | 14.59 | | 0.00 | 2275.82 | 2275.82 |
| 18-T02 | 2289.96 | 15.95 | | 0.00 | 2274.01 | 2274.01 | 16.90 | | 0.00 | 2273.06 | 2273.06 |
| 18-T03 | 2281.98 | 7.95 | | 0.00 | 2274.03 | 2274.03 | 8.36 | | 0.00 | 2273.62 | 2273.62 |
| 18-T04 | 2281.92 | 9.09 | | 0.00 | 2272.83 | 2272.83 | 9.36 | | 0.00 | 2272.56 | 2272.56 |
| 18-T05 | 2282.47 | 10.22 | | 0.00 | 2272.25 | 2272.25 | 10.76 | | 0.00 | 2271.71 | 2271.71 |
| 18-T06 | 2280.76 | 9.64 | | 0.00 | 2271.12 | 2271.12 | 10.46 | | 0.00 | 2270.30 | 2270.30 |
| 18-T07 | 2280.65 | 7.84 | | 0.00 | 2272.81 | 2272.81 | 8.34 | | 0.00 | 2272.31 | 2272.31 |
| 18-T08 | 2281.75 | 8.64 | | 0.00 | 2273.11 | 2273.11 | 8.94 | | 0.00 | 2272.81 | 2272.81 |
| 18-T09 | 2280.89 | 8.52 | | 0.00 | 2272.37 | 2272.37 | 9.09 | | 0.00 | 2271.80 | 2271.80 |
| 18-T10 | 2282.46 | 10.02 | 10.00 | 0.02 | 2272.44 | 2272.46 | 10.66 | 10.60 | 0.06 | 2271.80 | 2271.85 |
| 18-T11 | 2281.02 | 9.94 | | 0.00 | 2271.08 | 2271.08 | 10.59 | | 0.00 | 2270.43 | 2270.43 |
| 18-T12 | 2282.35 | 10.00 | | 0.00 | 2272.35 | 2272.35 | 10.56 | | 0.00 | 2271.79 | 2271.79 |
| 18-T13 | 2278.17 | 8.55 | | 0.00 | 2269.62 | 2269.62 | 8.38 | | 0.00 | 2269.79 | 2269.79 |
| 18-T14 | 2281.90 | 6.80 | | 0.00 | 2275.10 | 2275.10 | 8.01 | | 0.00 | 2273.89 | 2273.89 |
| 18-T15 | 2286.30 | 11.70 | | 0.00 | 2274.60 | 2274.60 | 12.29 | | 0.00 | 2274.01 | 2274.01 |
| 18-T16 | 2286.40 | 10.46 | | 0.00 | 2275.94 | 2275.94 | 10.75 | | 0.00 | 2275.65 | 2275.65 |
| 18-T17 | 2290.96 | 13.92 | | 0.00 | 2277.04 | 2277.04 | 14.43 | | 0.00 | 2276.53 | 2276.53 |
| 18-T18 | 2280.61 | 9.61 | | 0.00 | 2271.00 | 2271.00 | 10.15 | | 0.00 | 2270.46 | 2270.46 |
| 18-T19 | 2289.24 | 10.51 | | 0.00 | 2278.73 | 2278.73 | 10.58 | | 0.00 | 2278.66 | 2278.66 |
| 18-T20 | 2297.62 | 13.54 | | 0.00 | 2284.08 | 2284.08 | 13.09 | | 0.00 | 2284.53 | 2284.53 |
| 18-T22 | 2293.23 | 11.04 | | 0.00 | 2282.19 | 2282.19 | 11.29 | | 0.00 | 2281.94 | 2281.94 |
| 18-T23 | 2290.49 | 9.34 | | 0.00 | 2281.15 | 2281.15 | 10.55 | | 0.00 | 2279.94 | 2279.94 |
| 18-T24 | 2279.31 | 3.55 | | 0.00 | 2275.76 | 2275.76 | 4.92 | | 0.00 | 2274.39 | 2274.39 |
| 18-T25 | 2294.83 | 11.62 | | 0.00 | 2283.21 | 2283.21 | 12.29 | 11.09 | 1.20 | 2282.54 | 2283.45 |
| 18-T26 | 2280.99 | 9.88 | | 0.00 | 2271.11 | 2271.11 | 10.42 | | 0.00 | 2270.57 | 2270.57 |
| 18-MW01 | 2320.36 | 35.75 | | 0.00 | 2284.61 | 2284.61 | 35.00 | | 0.00 | 2285.36 | 2285.36 |
| 18-MW02 | 2300.00 | 17.10 | | 0.00 | 2282.90 | 2282.90 | 18.36 | | 0.00 | 2281.64 | 2281.64 |
| 18-MW03 | 2293.19 | 11.38 | | 0.00 | 2281.81 | 2281.81 | 12.76 | | 0.00 | 2280.43 | 2280.43 |
| 18-MW04 | 2281.21 | 6.54 | | 0.00 | 2274.67 | 2274.67 | 7.79 | | 0.00 | 2273.42 | 2273.42 |
| 18-MW05 | 2280.77 | 9.14 | | 0.00 | 2271.63 | 2271.63 | 10.62 | | 0.00 | 2270.15 | 2270.15 |
| 18-MW06 | 2275.72 | 7.68 | | 0.00 | 2268.04 | 2268.04 | 9.37 | | 0.00 | 2266.35 | 2266.35 |
| 18-MW07 | 2301.20 | 18.81 | | 0.00 | 2282.39 | 2282.39 | 19.80 | | 0.00 | 2281.40 | 2281.40 |
| 18-MW09 | 2285.91 | 7.52 | | 0.00 | 2278.39 | 2278.39 | 8.65 | | 0.00 | 2277.26 | 2277.26 |
| 18-MW10 | 2283.78 | 8.60 | | 0.00 | 2275.18 | 2275.18 | 9.85 | | 0.00 | 2273.93 | 2273.93 |
| 18-MW11 | 2281.38 | 9.75 | | 0.00 | 2271.63 | 2271.63 | 10.70 | | 0.00 | 2270.68 | 2270.68 |
| 18-MW12 | 2281.51 | 9.90 | | 0.00 | 2271.61 | 2271.61 | 10.33 | | 0.00 | 2271.18 | 2271.18 |
| 18-MW13 | 2288.06 | 14.42 | | 0.00 | 2273.64 | 2273.64 | 13.70 | | 0.00 | 2274.36 | 2274.36 |
| 18-MW14 | 2288.40 | 14.66 | | 0.00 | 2273.74 | 2273.74 | 14.10 | | 0.00 | 2274.30 | 2274.30 |
| 18-MW15 | 2291.70 | 17.52 | | 0.00 | 2274.18 | 2274.18 | 17.26 | | 0.00 | 2274.44 | 2274.44 |
| 18-MW16 | 2282.55 | 10.14 | | 0.00 | 2272.41 | 2272.41 | 10.62 | | 0.00 | 2271.93 | 2271.93 |
| 18-MW17 | 2276.07 | 7.70 | | 0.00 | 2268.37 | 2268.37 | 8.33 | | 0.00 | 2267.74 | 2267.74 |
| 18-MW18 | 2294.74 | 11.00 | | 0.00 | 2283.74 | 2283.74 | 14.01 | 8.80 | 5.21 | 2280.73 | 2284.70 |
| 18-MW20 | 2291.63 | 12.82 | | 0.00 | 2278.81 | 2278.81 | 12.66 | | 0.00 | 2278.97 | 2278.97 |
| 18-MW21 | 2291.86 | 12.98 | | 0.00 | 2278.88 | 2278.88 | 12.85 | | 0.00 | 2279.01 | 2279.01 |
| 18-MW22 | 2284.88 | 11.62 | | 0.00 | 2273.26 | 2273.26 | 12.21 | | 0.00 | 2272.67 | 2272.67 |
| 18-MW23 | 2284.29 | 11.02 | | 0.00 | 2273.27 | 2273.27 | 11.72 | | 0.00 | 2272.57 | 2272.57 |
| 18-MW24 | 2289.69 | 13.17 | | 0.00 | 2276.52 | 2276.52 | 13.52 | | 0.00 | 2276.17 | 2276.17 |
| 18-MW28 | 2284.51 | 9.78 | | 0.00 | 2274.73 | 2274.73 | 10.53 | | 0.00 | 2273.98 | 2273.98 |
| 18-OW1 | 2296.77 | 17.28 | | 0.00 | 2279.49 | 2279.49 | 17.36 | | 0.00 | 2279.41 | 2279.41 |
| 18-OW2 | 2296.63 | 17.10 | | 0.00 | 2279.53 | 2279.53 | 17.17 | | 0.00 | 2279.46 | 2279.46 |
| 18-PW1 | 2297.32 | 17.74 | | 0.00 | 2279.58 | 2279.58 | 17.82 | | 0.00 | 2279.50 | 2279.50 |

DTW Depth to water
DTF Depth to fuel
MSL Mean sea level
MP Measuring point

GROUNDWATER ELEVATIONS AND PRODUCT THICKNESS
EAFB MAIN BASE FLIGHT LINE SITE 18 (April 1993 thru April 1994)

| Well No. | MP Elev (FT MSL) | April 1994 DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
|---|---|---|---|---|---|---|
| 18-B01 | 2289.07 | | | | | |
| 18-B03 | 2290.49 | 16.5 | | 0.00 | 2273.99 | 2273.99 |
| 18-B04 | 2289.22 | 15.13 | | 0.00 | 2274.09 | 2274.09 |
| 18-B06 | 2286.22 | 13.41 | | 0.00 | 2272.81 | 2272.81 |
| 18-B07 | 2279.74 | 8.8 | 7.76 | 1.04 | 2270.94 | 2271.73 |
| 18-T01 | 2290.41 | 15.9 | | 0.00 | 2274.51 | 2274.51 |
| 18-T02 | 2289.96 | 17.38 | | 0.00 | 2272.58 | 2272.58 |
| 18-T03 | 2281.98 | 9.49 | | 0.00 | 2272.49 | 2272.49 |
| 18-T04 | 2281.92 | 10.76 | | 0.00 | 2271.16 | 2271.16 |
| 18-T05 | 2282.47 | 12.05 | | 0.00 | 2270.42 | 2270.42 |
| 18-T06 | 2280.76 | 11.64 | | 0.00 | 2269.12 | 2269.12 |
| 18-T07 | 2280.65 | 9.5 | | 0.00 | 2271.15 | 2271.15 |
| 18-T08 | 2281.75 | 10.36 | | 0.00 | 2271.39 | 2271.39 |
| 18-T09 | 2280.89 | 10.51 | | 0.00 | 2270.38 | 2270.38 |
| 18-T10 | 2282.46 | 11.91 | 11.62 | 0.29 | 2270.55 | 2270.77 |
| 18-T11 | 2281.02 | 11.77 | | 0.00 | 2269.25 | 2269.25 |
| 18-T12 | 2282.35 | 11.78 | | 0.00 | 2270.57 | 2270.57 |
| 18-T13 | 2278.17 | 9.43 | | 0.00 | 2268.74 | 2268.74 |
| 18-T14 | 2281.90 | 8.75 | | 0.00 | 2273.15 | 2273.15 |
| 18-T15 | 2286.30 | 13.55 | | 0.00 | 2272.75 | 2272.75 |
| 18-T16 | 2286.40 | 11.95 | | 0.00 | 2274.45 | 2274.45 |
| 18-T17 | 2290.96 | 16.03 | | 0.00 | 2274.93 | 2274.93 |
| 18-T18 | 2280.61 | 11.31 | | 0.00 | 2269.30 | 2269.30 |
| 18-T19 | 2289.24 | 11.89 | | 0.00 | 2277.35 | 2277.35 |
| 18-T20 | 2297.62 | 15.1 | | 0.00 | 2282.52 | 2282.52 |
| 18-T22 | 2293.23 | 12.55 | | 0.00 | 2280.68 | 2280.68 |
| 18-T23 | 2290.49 | 12.34 | | 0.00 | 2278.15 | 2278.15 |
| 18-T24 | 2279.31 | 5.04 | | 0.00 | 2274.27 | 2274.27 |
| 18-T25 | 2294.83 | 13.14 | 13.03 | 0.11 | 2281.69 | 2281.77 |
| 18-T26 | 2280.99 | 12.7 | | 0.00 | 2268.29 | 2268.29 |
| 18-MW01 | 2320.36 | 33.83 | | 0.00 | 2286.53 | 2286.53 |
| 18-MW02 | 2300.00 | 20.54 | | 0.00 | 2279.46 | 2279.46 |
| 18-MW03 | 2293.19 | 15.03 | | 0.00 | 2278.16 | 2278.16 |
| 18-MW04 | 2281.21 | 10.09 | | 0.00 | 2271.12 | 2271.12 |
| 18-MW05 | 2280.77 | 12.09 | | 0.00 | 2268.68 | 2268.68 |
| 18-MW06 | 2275.72 | 9.59 | | 0.00 | 2266.13 | 2266.13 |
| 18-MW07 | 2301.20 | 21.68 | | 0.00 | 2279.52 | 2279.52 |
| 18-MW09 | 2285.91 | 10 | | 0.00 | 2275.91 | 2275.91 |
| 18-MW10 | 2283.78 | 10.53 | | 0.00 | 2273.25 | 2273.25 |
| 18-MW11 | 2281.38 | 11.92 | | 0.00 | 2269.46 | 2269.46 |
| 18-MW12 | 2281.51 | 12.09 | | 0.00 | 2269.42 | 2269.42 |
| 18-MW13 | 2288.06 | 15.69 | | 0.00 | 2272.37 | 2272.37 |
| 18-MW14 | 2288.40 | 15.62 | | 0.00 | 2272.78 | 2272.78 |
| 18-MW15 | 2291.70 | 18.15 | | 0.00 | 2273.55 | 2273.55 |
| 18-MW16 | 2282.55 | 12.01 | | 0.00 | 2270.54 | 2270.54 |
| 18-MW17 | 2276.07 | 9.28 | | 0.00 | 2266.79 | 2266.79 |
| 18-MW18 | 2294.74 | 12.69 | | 0.00 | 2282.05 | 2282.05 |
| 18-MW20 | 2291.63 | 14.02 | | 0.00 | 2277.61 | 2277.61 |
| 18-MW21 | 2291.86 | 14.24 | | 0.00 | 2277.62 | 2277.62 |
| 18-MW22 | 2284.88 | 13.46 | | 0.00 | 2271.42 | 2271.42 |
| 18-MW23 | 2284.29 | 12.96 | | 0.00 | 2271.33 | 2271.33 |
| 18-MW24 | 2289.69 | 15.02 | | 0.00 | 2274.67 | 2274.67 |
| 18-MW28 | 2284.51 | 12.04 | | 0.00 | 2272.47 | 2272.47 |
| 18-OW1 | 2296.77 | 18.73 | | 0.00 | 2278.04 | 2278.04 |
| 18-OW2 | 2296.63 | 18.55 | | 0.00 | 2278.08 | 2278.08 |
| 18-PW1 | 2297.32 | 19.18 | | 0.00 | 2278.14 | 2278.14 |

DTW Depth to water
DTF Depth to fuel
MSL Mean sea level
MP Measuring point

GROUNDWATER ELEVATIONS AND PRODUCT THICKNESS
EAFB MAIN BASE FLIGHT LINE SITE 21 (April 1993 thru April 1994)

| | | APRIL 1993 | | | | | JULY 1993 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | MP Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
| 21-B01 | 2283.72 | 11.97 | | 0.00 | 2271.75 | 2271.75 | 12.08 | | 0.00 | 2271.64 | 2271.64 |
| 21-B03 | 2298.25 | 8.31 | | 0.00 | 2289.94 | 2289.94 | 8.97 | | 0.00 | 2289.28 | 2289.28 |
| 21-B05 | 2298.22 | 7.87 | 7.57 | 0.30 | 2290.35 | 2290.58 | 8.92 | 8.65 | 0.27 | 2289.30 | 2289.51 |
| 21-B06 | 2298.60 | 8.45 | | 0.00 | 2290.15 | 2290.15 | 9.12 | | 0.00 | 2289.48 | 2289.48 |
| 21-B11 | 2294.71 | 14.38 | | 0.00 | 2280.33 | 2280.33 | 14.75 | | 0.00 | 2279.96 | 2279.96 |
| 21-B14 | 2282.96 | 12.94 | | 0.00 | 2270.02 | 2270.02 | 12.72 | | 0.00 | 2270.24 | 2270.24 |
| 21-B15 | 2282.48 | 23.41 | | 0.00 | 2259.07 | 2259.07 | 22.66 | | 0.00 | 2259.82 | 2259.82 |
| 21-B18 | 2288.40 | 6.80 | | 0.00 | 2281.60 | 2281.60 | 7.27 | | 0.00 | 2281.13 | 2281.13 |
| 21-T01 | 2281.70 | 12.82 | | 0.00 | 2268.88 | 2268.88 | 12.37 | | 0.00 | 2269.33 | 2269.33 |
| 21-T02 | 2294.74 | 5.06 | | 0.00 | 2289.68 | 2289.68 | 5.52 | | 0.00 | 2289.22 | 2289.22 |
| 21-T03 | 2297.45 | 12.28 | | 0.00 | 2285.17 | 2285.17 | 12.58 | | 0.00 | 2284.87 | 2284.87 |
| 21-T04 | 2284.72 | 6.65 | | 0.00 | 2278.07 | 2278.07 | 6.72 | | 0.00 | 2278.00 | 2278.00 |
| 21-T05 | 2284.38 | 8.30 | | 0.00 | 2276.08 | 2276.08 | 8.57 | | 0.00 | 2275.81 | 2275.81 |
| 21-T06 | 2282.05 | 18.62 | | 0.00 | 2263.43 | 2263.43 | 17.76 | | 0.00 | 2264.29 | 2264.29 |
| 21-T07 | 2297.71 | 14.54 | | 0.00 | 2283.17 | 2283.17 | 14.86 | | 0.00 | 2282.85 | 2282.85 |
| 21-T08 | 2287.22 | 8.00 | | 0.00 | 2279.22 | 2279.22 | 8.56 | | 0.00 | 2278.66 | 2278.66 |
| 21-T09 | 2298.84 | 10.00 | | 0.00 | 2288.84 | 2288.84 | 8.86 | | 0.00 | 2289.98 | 2289.98 |
| 21-T10 | 2297.64 | 6.44 | | 0.00 | 2291.20 | 2291.20 | 8.66 | | 0.00 | 2288.98 | 2288.98 |
| 21-T11 | 2293.79 | 3.78 | 3.55 | 0.23 | 2290.01 | 2290.19 | 4.16 | 3.09 | 1.07 | 2289.63 | 2290.45 |
| 21-T12 | 2294.71 | 7.74 | | 0.00 | 2286.97 | 2286.97 | 8.32 | | 0.00 | 2286.39 | 2286.39 |
| 21-T13 | 2298.08 | 9.96 | | 0.00 | 2288.12 | 2288.12 | 10.87 | | 0.00 | 2287.21 | 2287.21 |
| 21-T14 | 2297.94 | 10.01 | | 0.00 | 2287.93 | 2287.93 | 9.95 | | 0.00 | 2287.99 | 2287.99 |
| 21-T15 | 2298.10 | 7.68 | | 0.00 | 2290.42 | 2290.42 | 10.17 | | 0.00 | 2287.93 | 2287.93 |
| 21-T16 | 2296.96 | 10.09 | | 0.00 | 2286.87 | 2286.87 | 10.39 | | 0.00 | 2286.57 | 2286.57 |
| 21-T17 | 2284.57 | 6.16 | | 0.00 | 2278.41 | 2278.41 | 6.42 | | 0.00 | 2278.15 | 2278.15 |
| 21-T18 | 2285.93 | 5.55 | | 0.00 | 2280.38 | 2280.38 | 5.90 | | 0.00 | 2280.03 | 2280.03 |
| 21-T19 | 2282.75 | 15.01 | | 0.00 | 2267.74 | 2267.74 | 14.12 | | 0.00 | 2268.63 | 2268.63 |
| 21-T20 | 2297.12 | 12.55 | | 0.00 | 2284.57 | 2284.57 | 12.73 | | 0.00 | 2284.39 | 2284.39 |
| 21-T21 | 2282.92 | 10.94 | | 0.00 | 2271.98 | 2271.98 | 11.00 | | 0.00 | 2271.92 | 2271.92 |
| 21-T22 | 2280.87 | 9.81 | 9.66 | 0.15 | 2271.06 | 2271.17 | 9.18 | | 0.00 | 2271.69 | 2271.69 |
| 21-T23 | 2280.20 | 10.25 | | 0.00 | 2269.95 | 2269.95 | 10.87 | | 0.00 | 2269.33 | 2269.33 |
| 21-T24 | 2275.01 | 6.52 | | 0.00 | 2268.49 | 2268.49 | 7.14 | | 0.00 | 2267.87 | 2267.87 |
| 21-T25 | 2275.86 | 7.19 | | 0.00 | 2268.67 | 2268.67 | 7.66 | | 0.00 | 2268.20 | 2268.20 |
| 21-T26 | 2276.24 | 8.61 | | 0.00 | 2267.63 | 2267.63 | 9.25 | | 0.00 | 2266.99 | 2266.99 |
| 21-T27 | 2298.39 | 13.74 | 13.65 | 0.09 | 2284.65 | 2284.72 | 13.42 | | 0.00 | 2284.97 | 2284.97 |
| 21-T29 | 2297.55 | 8.08 | 7.45 | 0.63 | 2289.47 | 2289.95 | 8.73 | 8.10 | 0.63 | 2288.82 | 2289.30 |
| 21-T30 | 2298.34 | 6.33 | | 0.00 | 2292.01 | 2292.01 | 7.22 | | 0.00 | 2291.12 | 2291.12 |
| 21-T31 | 2299.39 | 13.86 | | 0.00 | 2285.53 | 2285.53 | 13.96 | | 0.00 | 2285.43 | 2285.43 |
| 21-T33 | 2297.63 | 6.01 | | 0.00 | 2291.62 | 2291.62 | 7.49 | | 0.00 | 2290.14 | 2290.14 |
| 21-T34 | 2296.61 | | | | | | buried | | | | |
| 21-T35 | 2297.52 | 12.57 | | 0.00 | 2284.95 | 2284.95 | 12.59 | | 0.00 | 2284.93 | 2284.93 |
| 21-T36 | 2297.06 | 11.34 | | 0.00 | 2285.72 | 2285.72 | 12.59 | | 0.00 | 2284.47 | 2284.47 |
| 48 | 2293.42 | dry | | | | | dry | | | | |
| 49 | 2290.07 | 7.00 | | 0.00 | 2283.07 | 2283.07 | 7.64 | | 0.00 | 2282.43 | 2282.43 |
| 21-MW19 | 2313.67 | 27.88 | | 0.00 | 2285.79 | 2285.79 | 27.37 | | 0.00 | 2286.30 | 2286.30 |
| 21-MW27 | 2295.87 | 12.28 | | 0.00 | 2283.59 | 2283.59 | 12.66 | | 0.00 | 2283.21 | 2283.21 |
| 21-MW30 | 2284.09 | 11.56 | | 0.00 | 2272.53 | 2272.53 | 12.25 | | 0.00 | 2271.84 | 2271.84 |
| 21-MW31 | 2283.99 | 11.41 | | 0.00 | 2272.58 | 2272.58 | 12.10 | | 0.00 | 2271.89 | 2271.89 |
| 21-MW32 | 2276.80 | 11.00 | | 0.00 | 2265.80 | 2265.80 | 11.21 | | 0.00 | 2265.59 | 2265.59 |
| 21-MW34 | 2302.47 | 17.44 | | 0.00 | 2285.03 | 2285.03 | 17.81 | | 0.00 | 2284.66 | 2284.66 |
| 21-MW37 | 2297.96 | 8.00 | | 0.00 | 2289.96 | 2289.96 | 8.26 | | 0.00 | 2289.70 | 2289.70 |
| 21-MW38 | 2276.65 | 9.53 | | 0.00 | 2267.12 | 2267.12 | 9.25 | | 0.00 | 2267.40 | 2267.40 |
| 21-MW39 | 2277.24 | 10.14 | | 0.00 | 2267.10 | 2267.10 | 10.08 | | 0.00 | 2267.16 | 2267.16 |
| 21-MW40 | 2276.06 | 16.02 | | 0.00 | 2260.04 | 2260.04 | 15.80 | | 0.00 | 2260.26 | 2260.26 |
| 21-MW41 | 2276.31 | 16.33 | | 0.00 | 2259.98 | 2259.98 | 16.08 | | 0.00 | 2260.23 | 2260.23 |
| 21-MW43 | 2304.40 | 17.54 | | 0.00 | 2286.86 | 2286.86 | 17.70 | | 0.00 | 2286.70 | 2286.70 |
| 21-MW47 | 2281.93 | 9.48 | | 0.00 | 2272.45 | 2272.45 | 8.91 | | 0.00 | 2273.02 | 2273.02 |

GROUNDWATER ELEVATIONS AND PRODUCT THICKNESS
EAFB MAIN BASE FLIGHT LINE SITE 21 (April 1993 thru April 1994)

| | | OCTOBER 1993 | | | | | JANUARY 1994 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | MP Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
| 21-B01 | 2283.72 | 12.72 | | 0.00 | 2271.00 | 2271.00 | 13.27 | | 0.00 | 2270.45 | 2270.45 |
| 21-B03 | 2298.25 | 9.38 | | 0.00 | 2288.87 | 2288.87 | 6.59 | | 0.00 | 2291.66 | 2291.66 |
| 21-B05 | 2298.22 | 9.34 | 9.07 | 0.27 | 2288.88 | 2289.09 | 9.32 | | 0.00 | 2288.90 | 2288.90 |
| 21-B06 | 2298.60 | 9.46 | | 0.00 | 2289.14 | 2289.14 | 6.92 | | 0.00 | 2291.68 | 2291.68 |
| 21-B11 | 2294.71 | 15.29 | | 0.00 | 2279.42 | 2279.42 | 15.90 | | 0.00 | 2278.81 | 2278.81 |
| 21-B14 | 2282.96 | 13.07 | | 0.00 | 2269.89 | 2269.89 | 13.73 | | 0.00 | 2269.23 | 2269.23 |
| 21-B15 | 2282.48 | 22.46 | | 0.00 | 2260.02 | 2260.02 | 22.15 | | 0.00 | 2260.33 | 2260.33 |
| 21-B18 | 2288.40 | 7.98 | | 0.00 | 2280.42 | 2280.42 | 9.20 | | 0.00 | 2279.20 | 2279.20 |
| 21-T01 | 2281.70 | 12.66 | | 0.00 | 2269.04 | 2269.04 | 13.32 | | 0.00 | 2268.38 | 2268.38 |
| 21-T02 | 2294.74 | 5.79 | | 0.00 | 2288.95 | 2288.95 | 6.13 | | 0.00 | 2288.61 | 2288.61 |
| 21-T03 | 2297.45 | 12.88 | | 0.00 | 2284.57 | 2284.57 | 13.88 | | 0.00 | 2283.57 | 2283.57 |
| 21-T04 | 2284.72 | 7.25 | | 0.00 | 2277.47 | 2277.47 | 8.12 | | 0.00 | 2276.60 | 2276.60 |
| 21-T05 | 2284.38 | 9.31 | | 0.00 | 2275.07 | 2275.07 | 10.34 | | 0.00 | 2274.04 | 2274.04 |
| 21-T06 | 2282.05 | 17.67 | | 0.00 | 2264.38 | 2264.38 | 18.12 | | 0.00 | 2263.93 | 2263.93 |
| 21-T07 | 2297.71 | 15.44 | | 0.00 | 2282.27 | 2282.27 | 16.28 | | 0.00 | 2281.43 | 2281.43 |
| 21-T08 | 2287.22 | 8.40 | | 0.00 | 2278.82 | 2278.82 | 10.62 | | 0.00 | 2276.60 | 2276.60 |
| 21-T09 | 2298.84 | 9.00 | | 0.00 | 2289.84 | 2289.84 | 9.82 | | 0.00 | 2289.02 | 2289.02 |
| 21-T10 | 2297.64 | 10.35 | | 0.00 | 2287.29 | 2287.29 | 11.95 | | 0.00 | 2285.69 | 2285.69 |
| 21-T11 | 2293.79 | 4.20 | 4.00 | 0.20 | 2289.59 | 2289.74 | 4.43 | 4.40 | 0.03 | 2289.36 | 2289.38 |
| 21-T12 | 2294.71 | 8.36 | | 0.00 | 2286.35 | 2286.35 | 8.75 | | 0.00 | 2285.96 | 2285.96 |
| 21-T13 | 2298.08 | 11.70 | | 0.00 | 2286.38 | 2286.38 | 12.61 | | 0.00 | 2285.47 | 2285.47 |
| 21-T14 | 2297.94 | 10.10 | | 0.00 | 2287.84 | 2287.84 | 10.82 | | 0.00 | 2287.12 | 2287.12 |
| 21-T15 | 2298.10 | 11.97 | | 0.00 | 2286.13 | 2286.13 | 13.28 | | 0.00 | 2284.82 | 2284.82 |
| 21-T16 | 2296.96 | 11.09 | | 0.00 | 2285.87 | 2285.87 | 12.23 | | 0.00 | 2284.73 | 2284.73 |
| 21-T17 | 2284.57 | 6.83 | | 0.00 | 2277.74 | 2277.74 | 7.41 | | 0.00 | 2277.16 | 2277.16 |
| 21-T18 | 2285.93 | 6.45 | | 0.00 | 2279.48 | 2279.48 | 7.25 | | 0.00 | 2278.68 | 2278.68 |
| 21-T19 | 2282.75 | 13.90 | | 0.00 | 2268.85 | 2268.85 | 14.38 | | 0.00 | 2268.37 | 2268.37 |
| 21-T20 | 2297.12 | 13.29 | | 0.00 | 2283.83 | 2283.83 | 14.27 | | 0.00 | 2282.85 | 2282.85 |
| 21-T21 | 2282.92 | 11.58 | | 0.00 | 2271.34 | 2271.34 | 12.57 | | 0.00 | 2270.35 | 2270.35 |
| 21-T22 | 2280.87 | 10.91 | | 0.00 | 2269.96 | 2269.96 | 11.58 | | 0.00 | 2269.29 | 2269.29 |
| 21-T23 | 2280.20 | 11.45 | | 0.00 | 2268.75 | 2268.75 | 11.90 | | 0.00 | 2268.30 | 2268.30 |
| 21-T24 | 2275.01 | 7.58 | | 0.00 | 2267.43 | 2267.43 | 8.05 | | 0.00 | 2266.96 | 2266.96 |
| 21-T25 | 2275.86 | 8.20 | | 0.00 | 2267.66 | 2267.66 | 8.67 | | 0.00 | 2267.19 | 2267.19 |
| 21-T26 | 2276.24 | 9.36 | | 0.00 | 2266.88 | 2266.88 | 9.87 | | 0.00 | 2266.37 | 2266.37 |
| 21-T27 | 2298.39 | 14.31 | 13.77 | 0.54 | 2284.08 | 2284.49 | 14.57 | | 0.00 | 2283.82 | 2283.82 |
| 21-T29 | 2297.55 | 9.04 | 8.42 | 0.62 | 2288.51 | 2288.98 | 8.75 | | 0.00 | 2288.80 | 2288.80 |
| 21-T30 | 2298.34 | 7.79 | | 0.00 | 2290.55 | 2290.55 | 8.41 | | 0.00 | 2289.93 | 2289.93 |
| 21-T31 | 2299.39 | 14.05 | | 0.00 | 2285.34 | 2285.34 | 14.30 | | 0.00 | 2285.09 | 2285.09 |
| 21-T33 | 2297.63 | 8.32 | | 0.00 | 2289.31 | 2289.31 | 6.13 | | 0.00 | 2291.50 | 2291.50 |
| 21-T34 | 2296.61 | buried | | | | | XXXX | | | | |
| 21-T35 | 2297.52 | 13.41 | | 0.00 | 2284.11 | 2284.11 | 14.15 | | 0.00 | 2283.37 | 2283.37 |
| 21-T36 | 2297.06 | 13.11 | 12.95 | 0.16 | 2283.95 | 2284.07 | 13.70 | | 0.00 | 2283.36 | 2283.36 |
| 48 | 2293.42 | dry | | | | | dry | | | | |
| 49 | 2290.07 | 8.28 | | 0.00 | 2281.79 | 2281.79 | 8.98 | | 0.00 | 2281.09 | 2281.09 |
| 21-MW19 | 2313.67 | 28.40 | | 0.00 | 2285.27 | 2285.27 | 32.80 | | 0.00 | 2280.87 | 2280.87 |
| 21-MW27 | 2295.87 | 13.12 | | 0.00 | 2282.75 | 2282.75 | 13.75 | | 0.00 | 2282.12 | 2282.12 |
| 21-MW30 | 2284.09 | 12.92 | | 0.00 | 2271.17 | 2271.17 | 13.57 | | 0.00 | 2270.52 | 2270.52 |
| 21-MW31 | 2283.99 | 12.66 | | 0.00 | 2271.33 | 2271.33 | 13.31 | | 0.00 | 2270.68 | 2270.68 |
| 21-MW32 | 2276.80 | 11.60 | | 0.00 | 2265.20 | 2265.20 | 12.00 | | 0.00 | 2264.80 | 2264.80 |
| 21-MW34 | 2302.47 | 18.19 | | 0.00 | 2284.28 | 2284.28 | 18.78 | | 0.00 | 2283.69 | 2283.69 |
| 21-MW37 | 2297.96 | 8.49 | | 0.00 | 2289.47 | 2289.47 | 8.70 | | 0.00 | 2289.26 | 2289.26 |
| 21-MW38 | 2276.65 | 9.70 | | 0.00 | 2266.95 | 2266.95 | 10.32 | | 0.00 | 2266.33 | 2266.33 |
| 21-MW39 | 2277.24 | 10.52 | | 0.00 | 2266.72 | 2266.72 | 11.18 | | 0.00 | 2266.06 | 2266.06 |
| 21-MW40 | 2276.06 | 15.98 | | 0.00 | 2260.08 | 2260.08 | 16.20 | | 0.00 | 2259.86 | 2259.86 |
| 21-MW41 | 2276.31 | 16.25 | | 0.00 | 2260.06 | 2260.06 | 16.43 | | 0.00 | 2259.88 | 2259.88 |
| 21-MW43 | 2304.40 | 18.06 | | 0.00 | 2286.34 | 2286.34 | 18.63 | | 0.00 | 2285.77 | 2285.77 |
| 21-MW47 | 2281.93 | 9.58 | | 0.00 | 2272.35 | 2272.35 | 10.65 | | 0.00 | 2271.28 | 2271.28 |

GROUNDWATER ELEVATIONS AND PRODUCT THICKNESS
EAFB MAIN BASE FLIGHT LINE SITE 21 (April 1993 thru April 1994)

| Well No. | MP Elev (FT MSL) | April 1994 DTW (FT) | DTF (FT) | Fuel Thickness | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
|---|---|---|---|---|---|---|
| 21-B01 | 2283.72 | 14.07 | | 0.00 | 2269.65 | 2269.65 |
| 21-B03 | 2298.25 | 9.24 | | 0.00 | 2289.01 | 2289.01 |
| 21-B05 | 2298.22 | 8.88 | 8.72 | 0.16 | 2289.34 | 2289.46 |
| 21-B06 | 2298.60 | 9.28 | | 0.00 | 2289.32 | 2289.32 |
| 21-B11 | 2294.71 | 15.96 | | 0.00 | 2278.75 | 2278.75 |
| 21-B14 | 2282.96 | 14.13 | | 0.00 | 2268.83 | 2268.83 |
| 21-B15 | 2282.48 | 21.95 | | 0.00 | 2260.53 | 2260.53 |
| 21-B18 | 2288.40 | 9.45 | | 0.00 | 2278.95 | 2278.95 |
| 21-T01 | 2281.70 | 13.55 | | 0.00 | 2268.15 | 2268.15 |
| 21-T02 | 2294.74 | 5.65 | | 0.00 | 2289.09 | 2289.09 |
| 21-T03 | 2297.45 | 13.52 | | 0.00 | 2283.93 | 2283.93 |
| 21-T04 | 2284.72 | 8.33 | | 0.00 | 2276.39 | 2276.39 |
| 21-T05 | 2284.38 | 10.64 | | 0.00 | 2273.74 | 2273.74 |
| 21-T06 | 2282.05 | 18.73 | | 0.00 | 2263.32 | 2263.32 |
| 21-T07 | 2297.71 | 16.70 | | 0.00 | 2281.01 | 2281.01 |
| 21-T08 | 2287.22 | 11.16 | | 0.00 | 2276.06 | 2276.06 |
| 21-T09 | 2298.84 | 10.10 | | 0.00 | 2288.74 | 2288.74 |
| 21-T10 | 2297.64 | 12.51 | | 0.00 | 2285.13 | 2285.13 |
| 21-T11 | 2293.79 | 3.85 | 3.66 | 0.19 | 2289.94 | 2290.09 |
| 21-T12 | 2294.71 | 8.21 | | 0.00 | 2286.50 | 2286.50 |
| 21-T13 | 2298.08 | 12.41 | | 0.00 | 2285.67 | 2285.67 |
| 21-T14 | 2297.94 | 11.00 | | 0.00 | 2286.94 | 2286.94 |
| 21-T15 | 2298.10 | 13.38 | | 0.00 | 2284.72 | 2284.72 |
| 21-T16 | 2296.96 | 11.55 | | 0.00 | 2285.41 | 2285.41 |
| 21-T17 | 2284.57 | 7.63 | | 0.00 | 2276.94 | 2276.94 |
| 21-T18 | 2285.93 | 7.98 | | 0.00 | 2277.95 | 2277.95 |
| 21-T19 | 2282.75 | 14.83 | | 0.00 | 2267.92 | 2267.92 |
| 21-T20 | 2297.12 | 14.65 | | 0.00 | 2282.47 | 2282.47 |
| 21-T21 | 2282.92 | 12.85 | | 0.00 | 2270.07 | 2270.07 |
| 21-T22 | 2280.87 | 11.82 | 11.74 | 0.08 | 2269.05 | 2269.11 |
| 21-T23 | 2280.20 | 12.03 | | 0.00 | 2268.17 | 2268.17 |
| 21-T24 | 2275.01 | Dry | | | | |
| 21-T25 | 2275.86 | 8.84 | | 0.00 | 2267.02 | 2267.02 |
| 21-T26 | 2276.24 | 10.10 | | 0.00 | 2266.14 | 2266.14 |
| 21-T27 | 2298.39 | 15.16 | | 0.00 | 2283.23 | 2283.23 |
| 21-T29 | 2297.55 | 8.22 | 7.94 | 0.28 | 2289.33 | 2289.54 |
| 21-T30 | 2298.34 | 8.81 | | 0.00 | 2289.53 | 2289.53 |
| 21-T31 | 2299.39 | 14.27 | | 0.00 | 2285.12 | 2285.12 |
| 21-T33 | 2297.63 | 9.51 | | 0.00 | 2288.12 | 2288.12 |
| 21-T34 | 2296.61 | | | | | |
| 21-T35 | 2297.52 | 14.50 | | 0.00 | 2283.02 | 2283.02 |
| 21-T36 | 2297.06 | 14.10 | | 0.00 | 2282.96 | 2282.96 |
| 48 | 2293.42 | dry | | | | |
| 49 | 2290.07 | 9.21 | | 0.00 | 2280.86 | 2280.86 |
| 21-MW19 | 2313.67 | 27.95 | | 0.00 | 2285.72 | 2285.72 |
| 21-MW27 | 2295.87 | | | | | |
| 21-MW30 | 2284.09 | 13.74 | | 0.00 | 2270.35 | 2270.35 |
| 21-MW31 | 2283.99 | 13.59 | | 0.00 | 2270.40 | 2270.40 |
| 21-MW32 | 2276.80 | 12.21 | | 0.00 | 2264.59 | 2264.59 |
| 21-MW34 | 2302.47 | 18.94 | | 0.00 | 2283.53 | 2283.53 |
| 21-MW37 | 2297.96 | 8.37 | | 0.00 | 2289.59 | 2289.59 |
| 21-MW38 | 2276.65 | 10.63 | | 0.00 | 2266.02 | 2266.02 |
| 21-MW39 | 2277.24 | 11.46 | | 0.00 | 2265.78 | 2265.78 |
| 21-MW40 | 2276.06 | 16.54 | | 0.00 | 2259.52 | 2259.52 |
| 21-MW41 | 2276.31 | 16.80 | | 0.00 | 2259.51 | 2259.51 |
| 21-MW43 | 2304.40 | 18.56 | | 0.00 | 2285.84 | 2285.84 |
| 21-MW47 | 2281.93 | 10.96 | | 0.00 | 2270.97 | 2270.97 |

GROUNDWATER ELEVATIONS AND PRODUCT THICKNESS
EAFB MAIN BASE FLIGHT LINE SITE 11, SITE 24 AND PRL 56 (April 1993 thru April 1994)

| | | APRIL 1993 | | | | | JULY 1993 | | | | | OCTOBER 1993 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | MP Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thicknes | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thicknes | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) | DTW (FT) | DTF (FT) | Fuel Thicknes | WL Elev (FT MSL) | Corrected WL Elev (FT MSL) |
| 11-MW09 | 2286.92 | 26.61 | | 0.00 | 2260.31 | 2260.31 | 26.10 | | 0.00 | 2260.82 | 2260.82 | 26.02 | | 0.00 | 2260.90 | 2260.90 |
| 11-MW10 | 2286.07 | 31.79 | | 0.00 | 2254.28 | 2254.28 | 31.65 | 28.70 | 2.95 | 2254.42 | 2256.67 | 31.50 | 28.70 | 2.80 | 2254.57 | 2256.70 |
| 11-MW11 | 2285.80 | 32.11 | | 0.00 | 2253.69 | 2253.69 | 31.85 | | 0.00 | 2253.95 | 2253.95 | 31.80 | | 0.00 | 2254.00 | 2254.00 |
| 11-MW68 | 2288.08 | | | | | | | | | | | | | | | |
| 24-MW26 | 2309.19 | 22.42 | 22.42 | 0.00 | 2286.77 | 2286.77 | 23.11 | 22.42 | 0.69 | 2286.08 | 2286.61 | 24.68 | 22.45 | 2.23 | 2284.51 | 2286.21 |
| 56-MW66 | 2294.38 | 13.42 | 9.36 | 4.06 | | | 14.01 | 8.80 | | 2280.37 | 2280.37 | 14.74 | 10.60 | 4.14 | 2279.64 | 2282.80 |

DTW Depth to water
DTF Depth to fuel

MSL Mean sea level
MP Measuring point

# APPENDIX B

# EVALUATION OF THE INTERNAL COMBUSTION ENGINE UNIT

# A PERFORMANCE AND COST EVALUATION OF INTERNAL COMBUSTION ENGINES FOR THE DESTRUCTION OF HYDROCARBON VAPORS FROM FUEL-CONTAMINATED SOILS

DECEMBER 1994

Distribution is unlimited; approved for public release

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
TECHNOLOGY TRANSFER DIVISION

# A PERFORMANCE AND COST EVALUATION OF INTERNAL COMBUSTION ENGINES FOR THE DESTRUCTION OF HYDROCARBON VAPORS FROM FUEL-CONTAMINATED SOILS

by

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Denver, Colorado

for

U.S. Air Force

Center for Environmental Excellence

Brooks Air Force Base, Texas

# CONTENTS

# SECTION 1

# INTRODUCTION

This document describes the performance and costs associated with a modified internal combustion engine (ICE) used for the destruction of hydrocarbon vapors extracted from fuel contaminated soils. During the period of 18 October 1993 to 14 January 1994, an ICE treatment system manufactured by VR Systems Inc. in Anaheim, California was tested at the Patrick Air Force Base (AFB), Florida, active Base Exchange (BX) service station. The ICE test was conducted in conjunction with an ongoing soil vapor extraction/bioventing pilot test directed and funded by the Air Force Center for Environmental Excellence (AFCEE), Technology Transfer Division (ERT). The purpose of this test was to independently measure both the performance and the cost of ICE operation, and to determine how this technology can be most effectively used to complement the bioventing technology.

Bioventing is an *in situ* remediation technology which is best suited for less volatile hydrocarbons commonly found in jet fuels, diesel fuels, and heating oils. Bioventing can be accomplished through air injection or extraction; however, injection of air into sites contaminated with more volatile hydrocarbon products (e.g., gasoline) can result in uncontrolled migration of high concentrations of volatile organic compounds (VOCs).. One solution to this problem is the use of soil vapor extraction techniques during the initial months of remediation to remove and treat high levels of soil gas VOCs. Additionally, while the VOCs are being extracted from the soil, they are replaced by atmospheric air which contains the oxygen (i.e., electron acceptor) required to subsequently promote *in situ* biodegradation. This short period of vapor extraction (higher cost) is then followed by long-term air injection (lower cost) to provide oxygen for the biodegradation of less volatile or adsorbed hydrocarbons in the soil.

In many states, VOCs must be treated before discharge into the atmosphere. In the State of Florida, soil vapor extraction must include a vapor treatment technology capable of removing 99 percent of the VOCs prior to discharge. Activated carbon cannisters and thermal destruction units, such as ICEs, are used for treatment of hydrocarbon vapors. Significant information on the performance and cost of activated carbon is already available. Less information is available on ICE performance, particularly data that have been independently measured and verified.

This document is organized into five sections including this introduction. Section 2 provides a more complete description of the technology and the vendor's information on performance and cost. Section 3 reports the results of the 3-month field test with an

# SECTION 2

# DESCRIPTION OF TECHNOLOGY

## 2.1 VAPOR EXTRACTION AND COMBUSTION

Vapor extraction and combustion is an innovative technology which uses a gasoline-burning ICE with advanced emission controls to extract and burn hydrocarbon vapors from the vadose zone of contaminated soil. Vapors are extracted from the ground by the intake manifold vacuum of the engine. The vapors are then burned as fuel to run the engine. The exhaust gases pass through catalytic converters for final purification before exiting to the atmosphere.

VR Systems, Inc. of Anaheim, California[1] has developed a vapor extraction technology which incorporates the use of a modified ICE. The VR Systems Model V3 unit uses a Ford Motor Company® 460-cubic-inch-displacement (CID) engine block, heads, and accessories along with an onboard computer system which monitors engine performance. The intake manifold of the engine provides the vacuum source, up to 18 inches of mercury (Hg) or approximately 245 inches of water. Flow rates range from 0 to 250 standard cubic feet per minute (scfm), depending on soil conditions and the hydrocarbon concentrations of the extracted soil gas.

The VR System units are not designed to remove or treat chlorinated vapors from soil. These vapors once thermally treated can produce an off-gas air steam containing hydrochloric acid (HCl) vapor and potentially other highly toxic gases, depending on which type of chlorinated vapor is being destroyed. Additionally, the highly corrosive vapors produced as a treatment by-product destroys the engine and related equipment. There are other thermal oxidation systems equipped with condensing units (scrubbers) on the exhaust to effectively treat chlorinated vapors.

The VR System units are designed to remove nonchlorinated hydrocarbon vapors from contaminated soil utilizing a vapor extraction vent well like the one installed at the Patrick AFB, BX Service Station as part of the bioventing pilot test (ES, 1993). The extracted vapors flow through a computer-monitored fuel control system, and into the intake manifold of the engine. Destruction of the majority of hydrocarbon vapors occurs through combustion within the engine. Exhaust gases from the engine pass through a small catalytic converter which completes the treatment process.

An on-board computer system provides the necessary monitoring for engine control. The data acquisition system includes a 16-channel data reporting system which

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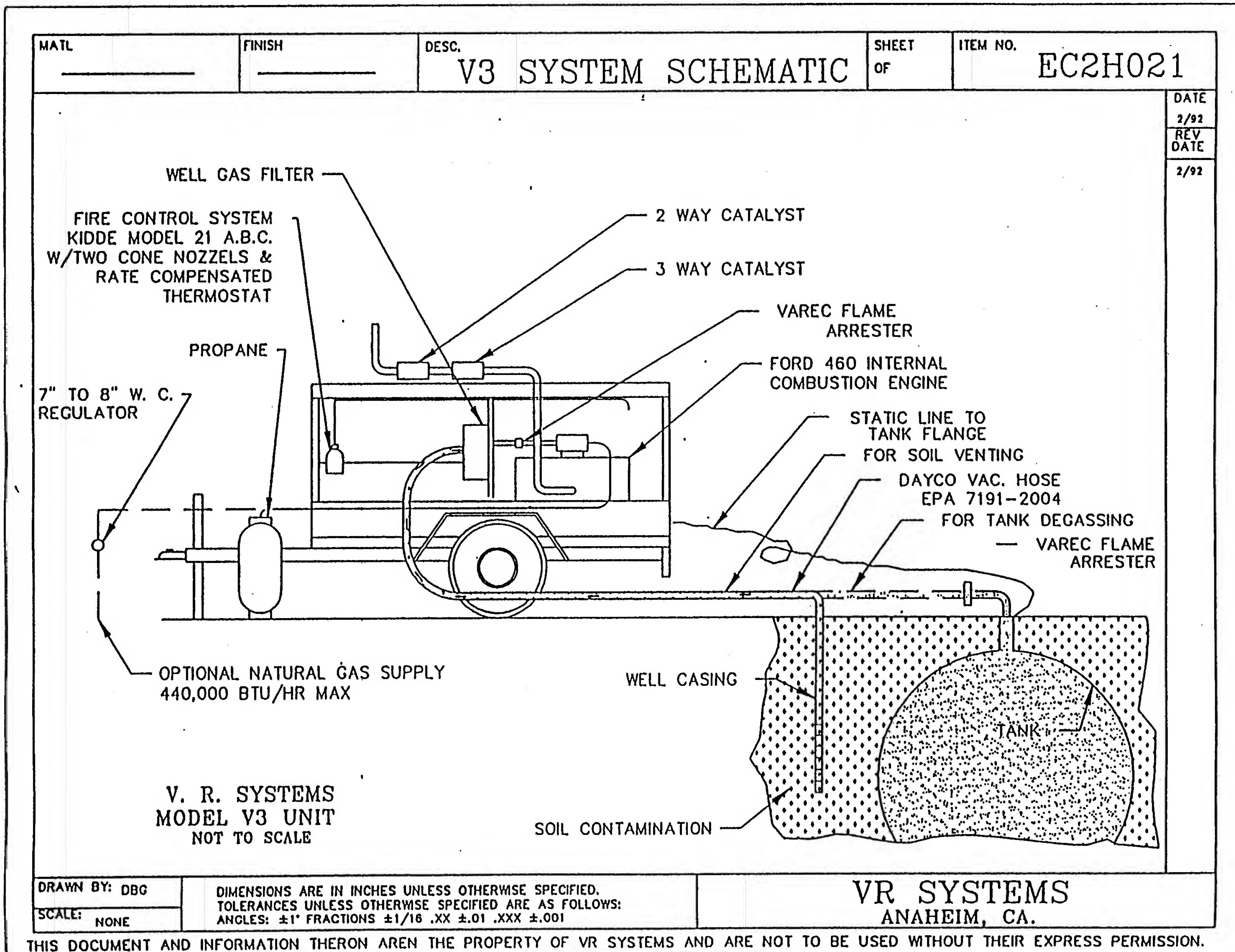
[1] Point of Contact: Mr. Tom Davis, Telephone: 714-826-0483, FAX: 714-826-8746

Figure 2.1



MATL
FINISH
DESC.
V3 SYSTEM SCHEMATIC
SHEET
OF
ITEM NO.
EC2H021
DATE
2/92
REV DATE
2/92
WELL GAS FILTER
FIRE CONTROL SYSTEM KIDDE MODEL 21 A.B.C. W/TWO CONE NOZZELS & RATE COMPENSATED THERMOSTAT
2 WAY CATALYST
3 WAY CATALYST
VAREC FLAME ARRESTER
PROPANE
FORD 460 INTERNAL COMBUSTION ENGINE
7" TO 8" W. C. REGULATOR
STATIC LINE TO TANK FLANGE
FOR SOIL VENTING
DAYCO VAC. HOSE EPA 7191-2004
FOR TANK DEGASSING
VAREC FLAME ARRESTER
OPTIONAL NATURAL GAS SUPPLY 440,000 BTU/HR MAX
WELL CASING
TANK
V. R. SYSTEMS
MODEL V3 UNIT
NOT TO SCALE
SOIL CONTAMINATION
DRAWN BY: DBG
SCALE: NONE
DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ±1° FRACTIONS ±1/16 .XX ±.01 .XXX ±.001
VR SYSTEMS
ANAHEIM, CA.
THIS DOCUMENT AND INFORMATION THERON AREN THE PROPERTY OF VR SYSTEMS AND ARE NOT TO BE USED WITHOUT THEIR EXPRESS PERMISSION.

TABLE 2.2

MANUFACTURER PERFORMANCE SPECIFICATIONS
FOR VR SYSTEMS MODELS V2C, V3, AND V4
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION
PATRICK AFB, FLORIDA

| Feature | V2C | V3 | V4 |
|---|---|---|---|
| Max. Hydrocarbon Destruction Rate | 15 lbs/hr | 55 lbs/hr | 110 lbs/hr |
| Destruction Efficiency for TVH/BTEX[a/] | >99% | >99% | >99% |
| Engine Size in Cubic Inch Displacement | 140 | 460 | 920 (2 x 460) |
| Max. Flow Rate in Cubic Feet/Min | 65 | 250 | 500 |
| Max. Vacuum in Inches of Mercury/Approx. Inches of Water | 18/245 | 18/245 | 18/245 |
| Required Soil Gas Hydrocarbon concentration (ppmv as gasoline)[b/] | 40,000 | 40,000 | 40,000 |

a/ TVH = total volatile hydrocarbons; BTEX = benzene, tolune, ethylbenzene, and xylenes.

b/ The influent vapor concentration in ppmv = parts per million, volume per volume required to sustain >99% destruction efficiency without the addition of supplemental fuel (propane or natural gas).

TABLE 2.3

CAPITAL AND OPERATING COSTS
(2/15/94)
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION
PATRICK AFB, FLORIDA

| Cost Item | V2C | V3 | V4 |
|---|---|---|---|
| Purchase | $40,450.00 | $73,450.00 | 98,880.00 |
| Rental (Monthly) | $3,480.00 | $6,235.00 | $8,923.00 |
| Mobilization/Demobilization 500 miles from vendor via commercial carrier | $1,000.00 | $1,000.00 | $1,400.00 |
| Daily Maximum Supplemental Fuel Costs (Approx.)@ 2,000-rpm Engine Speed (Assumes all BTUs are supplied by supplemental fuel - propane at $0.80/gal.) | $20.00 | $70.00 | $140.00 |
| Monthly Service Maintenance[a] (Approximate as of 2/16/94) | $220.00 | $220.00 | $374.00 |
| Miscellaneous Services/Equipment[b] (As required as of 2/16/94) | | | |

a/ Monthly service estimates include: engine oil, oil filters, air filter(s), spark plugs, well gas filter(s), and labor (performed by a VR Systems trained technician).

b/ Additional labor and equipment pricing as required may include:

- Maintenance Labor @ $45/hr.
- Travel time @ $30.00/hr.
- Mileage (first 20 miles free) @ $0.28/mi.
- Long Distance (requiring air travel), air fare plus per diem
- Additional equipment not included in the monthly service, will be installed only as required are:
  - Computer air cleaner @$7.22/each
  - Distributor cap @ $23.75/each
  - Spark plug wires @$63.00/set
  - Rotor @ $3.82/each

Note: All materials shown are at retail cost, and can be purchased in bulk for generally 40 to 50% less.

# SECTION 3

# FIELD DEMONSTRATION RESULTS

## 3.1 SITE DESCRIPTION

An extended pilot study evaluation of the Model V3 vapor extraction ICE unit was conducted between October 18, 1993 and January 14, 1994. The field demonstration was performed at Patrick AFB, Florida at the BX Service Station.

The BX Service Station site is part of an ongoing bioventing pilot test study. Soil and groundwater contamination exists from previous unleaded gasoline leaks from underground storage tanks (USTs). A soil gas survey was initially conducted to verify site conditions, and to ensure that sufficient soil contamination existed to conduct the bioventing pilot test. The initial soil gas sample laboratory results ranged from 38,000 parts per million, volume per volume (ppmv) to 100,000 ppmv for total volatile hydrocarbons (TVH) within the study area (ES, 1993).

The average water table depth is approximately 5 feet below ground surface (bgs). A horizontal vent well (HVW) was installed at 4 feet bgs as part of the bioventing pilot test. The HVW was placed in the center of the highest TVH readings obtained during the initial soil gas survey at this site. The HVW was constructed of 4-inch, Schedule 40 polyvinyl chloride (PVC) pipe with 30 feet of 0.03-inch slotted well screen. The entire length of screened interval was placed within the contaminated soil area. The entire study area at this site is paved, which significantly reduces or eliminates the potential for short-circuiting and increases the area of influence for air injection or soil vapor extraction through the HVW.

Because initial soil vapor concentrations at this site were very high, bioventing through the use of air injection was ruled out due to the potential for vapor migration. Soil vapor extraction was required to significantly reduce soil vapor concentrations before the system could be converted to a more standard air injection bioventing system. Several emission control technologies were evaluated based on efficiency, maximum TVH influent concentration capacities, maintenance requirements, and cost over the period necessary for vapor extraction. Based on the technology review, a decision was made to use the ICE vapor extraction system manufactured by VR Systems, Inc. and to evaluate its performance and cost of operation.

## 3.2. REGULATORY APPROVAL/REQUIREMENTS

Florida Department of Environmental Protection (FDEP) policy states that all vacuum extraction units must use a catalytic or thermal oxidation device, or its

## TABLE 3.1

## CHANGE IN INFLUENT CONCENTRATIONS FOR TVH AND BTEX OVER TIME @ 150 SCFM VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION PATRICK AFB, FLORIDA

| | Concentrations | |
|---|---|---|
| Influent Constituent | Initial (ppmv) | After 2-Days (ppmv) |
| TVH | 26,800 | 4,400 |
| Benzene | —[a] | —[a] |
| Toluene | 15 | 4.7 |
| Ethylbenzene | 14 | 12 |
| Xylenes | 200 | 110 |

[a] Below Detection Limit.

During the 2-day initial test period, a variety of rpm ranges were used to find the optimum engine speed which yielded the highest vapor flow from the well, while using the least amount of supplemental propane. Also, during the initial 13 hours of operation, the VR System engine was treating a severely oxygen-depleted soil gas. Bioactivity in the area had completely depleted soil gas oxygen supplies. Adjustments by the onboard computer of the influent flow rates were made to maintain the proper oxygen/fuel ratio and a VOC destruction efficiency of >99 percent. As the influent soil gas was oxygen depleted (<2%), the computer had to compensate by adding dilution air through the carburetor and supplemental propane until the soil gas oxygen supply increased to greater than 17 to 18 percent. The majority of the supplemental fuel used over the course of the 2-day test was consumed during this initial 13-hour adjustment period.

Propane consumption during the initial 2 days (44 hours) was 1,925 cubic feet (cf) at an average rate of 43.75 cf/hour. Propane costs during this test were $0.80 per gallon. Using a conversion factor of 36 cf/gallon of propane, an average cost for the supplemental fuel propane was approximately $1.00/hr. Based on laboratory influent and effluent sampling results, the cost per kilogram (kg) of TVH and BTEX destroyed was calculated. Based on the laboratory results and an initial flow rate of 150 scfm, a graphical representation of the cost per kg of TVH and BTEX destroyed was generated for the initial 800,000 standard cubic feet (SCF) of soil gas treated during the first 5 days of operation (Figure 3.1). During this period, the average operating cost was $325.00 per day. A breakdown of the daily operating cost is as follows:

- Equipment rental $230.00/day,
- Supplemental fuel (propane) $24.00 to $57.00/day, and
- Labor (1 hour per day) $50.00/hour to check on and sample system.

As the actual daily costs ranged from $305.00 to $337.00, an average daily cost of $325.00 was used.

During the initial startup of vapor extraction, the soil gas being removed will typically be oxygen depleted and contain elevated concentrations of carbon dioxide ($CO_2$) and methane, which are produced by the *in situ* biological activity. During the initial 800,000 scf of soil gas removal at Patrick AFB, a wide range of operating costs were observed. After the initial soil gas had been replaced by oxygenated soil gas, the need for dilution air subsided and contaminant destruction rates became more uniform.

The ratio of BTEX to TVH at this site is not representative of a recent spill or leak, where BTEX comprises up to 20 percent of the TVH. It appears that the majority of the BTEX constituents normally expected in unweathered gasoline were no longer present. During the initial startup period at this site, BTEX comprised 5 percent of the TVH, indicating an older (weathered) gasoline. The cost for each kilogram of BTEX destroyed will vary based on the site-specific BTEX concentrations. At this site, costs for BTEX destruction were high due to the low percentage of BTEX in the residual fuel.

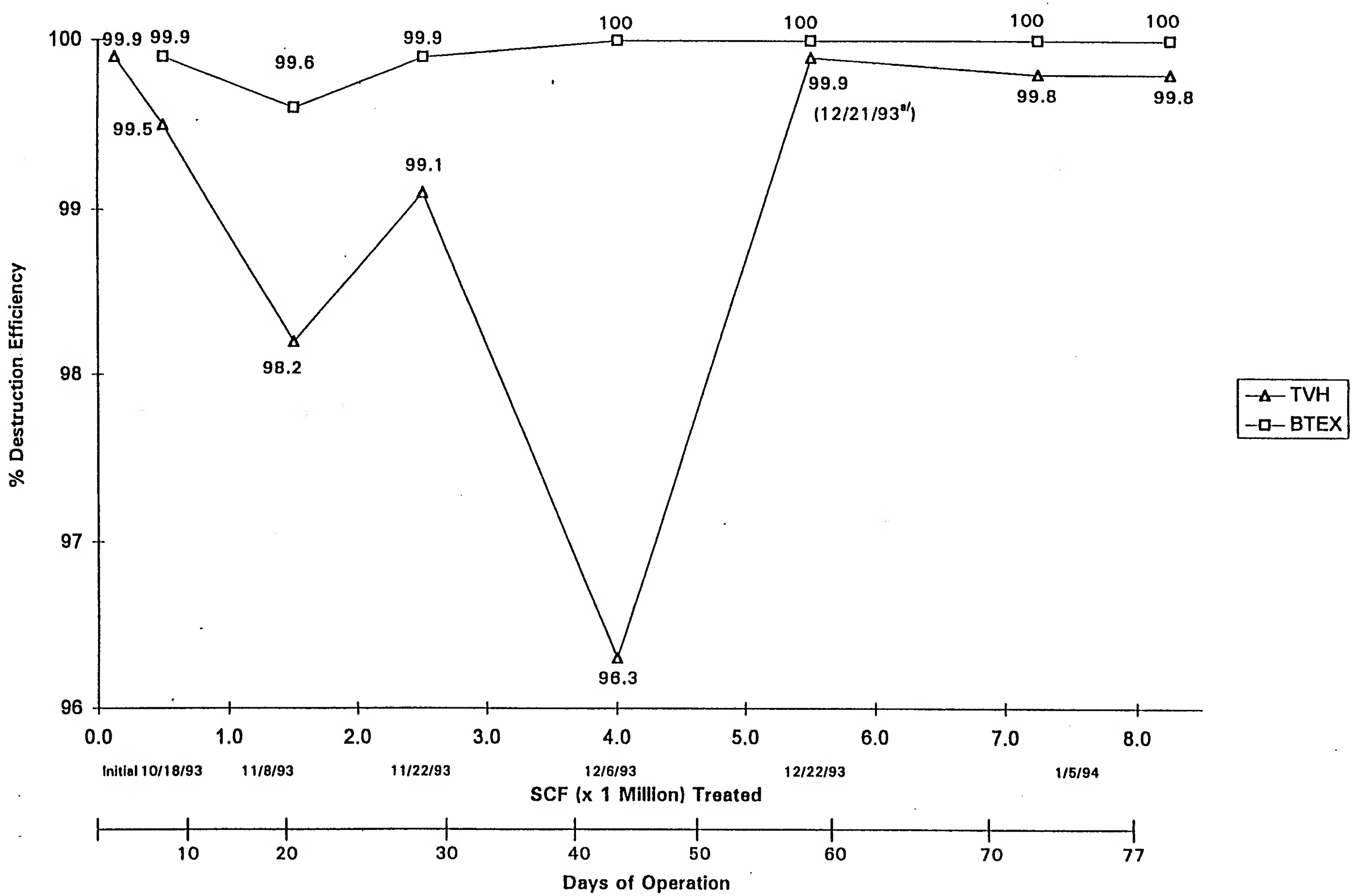
### 3.4.2 Long-Term (Weeks 2-13) Performance

During the extended test period, the average flow rate was reduced from 150 scfm (initially) to 80 scfm due to a seasonally high water table which reduced the HVW efficiency. To minimize upconing, the onboard computer was programmed to operate the engine at 7 to 11 inches of water vacuum to prevent high-water shut down of the equipment. Limitations placed on the vacuum reduced the overall efficiency of the V3 unit. Despite these inefficiencies, the primary goals of determining the destruction efficiency, operating cost range, reliability, and maintainability were successfully achieved during the evaluation.

### 3.4.3 Destruction Efficiency

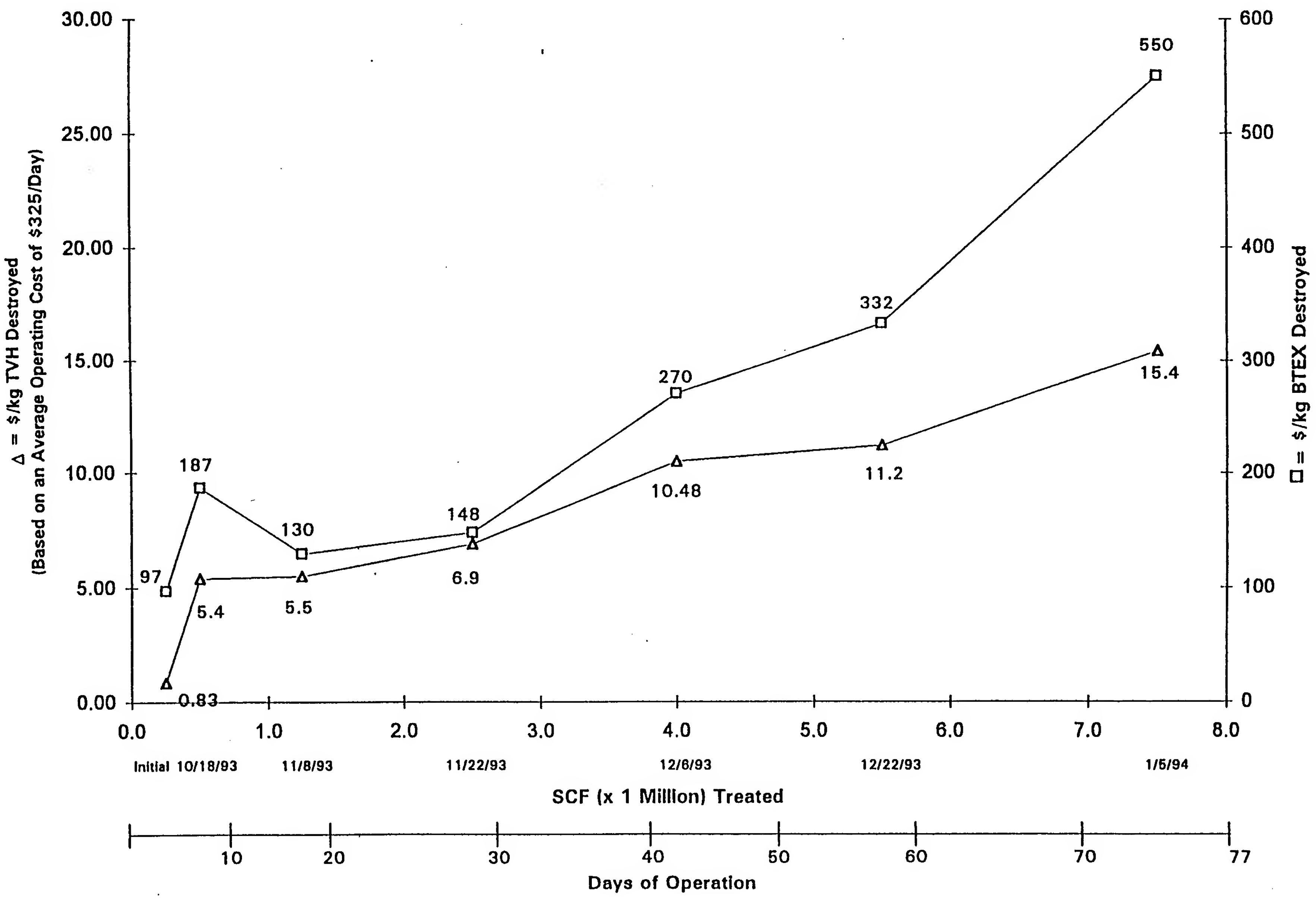
The VR System provided greater than 99-percent destruction efficiency for BTEX and greater than 96-percent destruction efficiency for TVH throughout the test period. Figure 3.2 illustrates the range of soil gas influent BTEX and TVH concentrations encountered during the test and the significant reduction that occurred as a result of 80 days of soil vapor extraction. Figure 3.3 illustrates the destruction efficiencies that were achieved. A 4-percent reduction in TVH destruction efficiency occurred when the engine rings and valves began to wear, allowing a fraction of the supplemental propane to pass unburned through the engine exhaust. When a new replacement unit was installed at the site, destruction efficiencies returned to greater than 99 percent for all hydrocarbons. It is important to note that laboratory analysis confirmed that the unburned fuel was propane and not BTEX compounds from the soil vapor extraction

## Figure 3.3
## VR Systems Destruction Efficiency for BTEX and TVH of Influent Vs. Effluent




[a] NOTE: 12/21/93 Replaced VR Systems Unit With Upgraded V3 Model.

# Figure 3.4
## Cost Per Kilogram of BTEX and TVH Destroyed at 80 SCFM Flow Rate



# SECTION 4

# SUMMARY

## 4.1 TECHNOLOGY PERFORMANCE

### 4.1.1 Destruction Efficiency

During the 3-month Patrick AFB test, soil gas TVH concentrations were reduced from 26,800 to 1,600 ppmv and BTEX concentrations were reduced from 230 ppmv to 44 ppmv (Figure 3.2). Throughout the test period, greater than 99-percent destruction of BTEX was achieved by the ICE. TVH destruction ranged from 96 to 99+ percent. The 4-percent loss in TVH destruction efficiency occurred when worn engine rings and valves allowed unburned propane (supplemental fuel) to pass through the unit. When a newer ICE replaced the worn unit, TVH destruction efficiencies returned to greater than 99 percent.

### 4.1.2 Reliability

Following an initial week of system startup and optimization, the VR System unit operated with minimum interruptions. During the 3-month test, the unit experienced four unscheduled shutdowns accounting for 12 percent of the 2,160 available operating hours. Two of the unscheduled shutdowns were associated with repairs to the engine rings and valve assembly and ICE replacement, which were required to maintain a 99-percent destruction efficiency, and two shutdowns were due to a high water table condition at the site resulting in the need for installing a water knock-out drum before the unit. A factory representative completed the engine repairs at no additional cost to the Air Force.

Based on this test, weekly influent and effluent TVH sampling is recommended to verify system performance and to identify potential VOC pass through resulting from worn engine parts. This sampling can be accomplished with handheld instruments which are capable of detecting unburned propane as well as other fuel hydrocarbons.

The reliability of ICE systems also depends on the engineered elimination of condensate from the extracted soil vapor. The VR System unit is equipped with a water sensor which will automatically shut down the system when water approaches the carburetor intake. A water knockout drum is recommended for all applications, but is particularly important on sites with shallow aquifers where groundwater can be pulled into the vapor extraction system. At the Patrick AFB site, flow rates were reduced and a knockout drum was placed in front of the ICE to prevent ICE shutdown during seasonally high water table conditions.

### 4.2.3 Cost Per Kilogram of TVH/BTEX

The unit cost for each kg of TVH (including BTEX) or specifically for BTEX destroyed is a convenient way of comparing different vapor treatment technologies. The ICE system used at the Patrick AFB site was oversized, and unit costs derived from this test are considered conservative. During the initial days of operation when VOC concentrations were high, TVH treatment costs as low as $0.48 per kilogram were achieved. During the final days of operation, TVH treatment costs had increased to $15.40 per kilogram. BTEX treatment costs ranged from $49 to $550 per kilogram (Figure 3.4). These costs are site specific and were inflated at the Patrick AFB BX Site due the low BTEX content of the soil gas .

## 4.3 Integration With *In Situ* Bioventing

At sites with high levels (>10,000 ppmv) of soil gas TVH, it may be necessary to extract these vapors before long-term air injection/bioventing can begin. Of particular concern are sites with gasoline- or light-distillate-contaminated soils and sites near buildings and utility corridors which could be adversely impacted by vapor migration caused by air injection.

Based on both vendor information and Patrick AFB tests, the ICE technology is an effective method of controlling vapor emissions and destroying contaminants. These units are most effective when initial soil gas TVH is greater than 40,000 ppmv. At these high concentrations, the ICE will operate without supplemental fuel. ICE units come in a variety of sizes and can be optimized based on the desired soil vapor extraction rate and site-specific soil gas permeability.

The length of ICE operation at each site will depend on several factors. The decision to begin air injection bioventing must be based on the potential risk of vapor migration into buildings and utility corridors and the ability of soil bacteria to biodegrade mobilized VOCs. Biodegradation rates established during bioventing pilot tests can be used to determine the approximate mass of soil "biofilter" required to biodegrade a known mass of migrating hydrocarbons. By minimizing air flow rates to just satisfy *in situ* oxygen demand, the flux of volatile hydrocarbons to the atmosphere from the contaminated soil will also be minimized.

## 4.4 Future Work

Other *ex situ* vapor treatment technologies have been evaluated including the Biocube® and PURUS PADRE®. Reports similar to this will be provided on each technology. A summary report will compare cost and performance of each and assist in remedial design decisions.

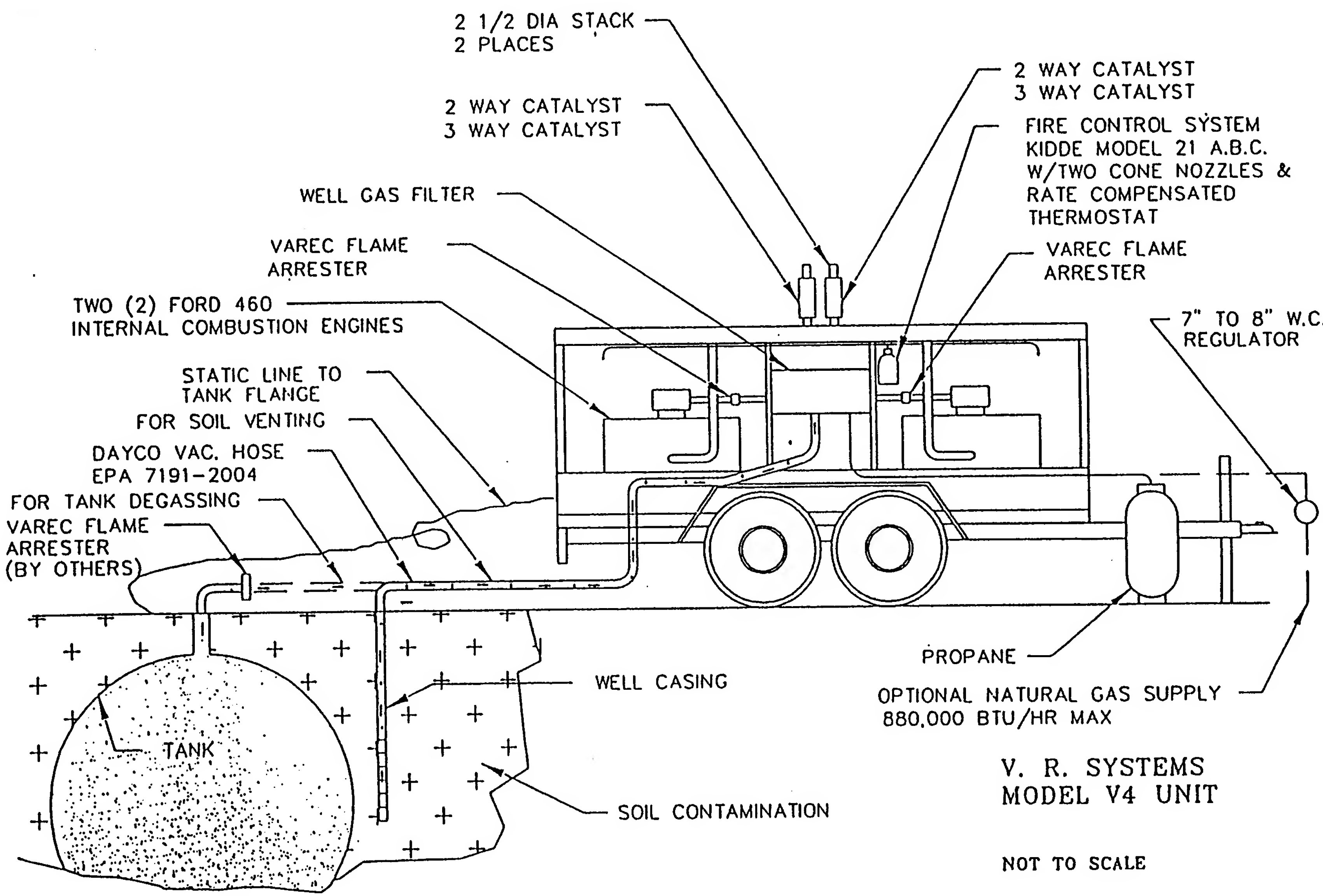
# REFERENCES

Engineering Science, Inc. 1993. *Interim Test Results Report for Bioventing at the Patrick AFB BX Service Station*. Report provided to the Air Force Center for Environmental Excellence (AFCEE/ERT).

# APPENDIX A

MATL | FINISH | DESC. V4 SYSTEM SCHEMATIC | SHEET OF | ITEM NO. EC2H020

| DATE | REV DATE | A | B |
|---|---|---|---|
| 2-92 | 2-92 | 6-93 | 12-93 |




DRAWN BY: DBG

DIMENSIONS ARE IN INCHES UNLESS OTHERWSE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:

VR SYSTEMS

**VR systems inc.**

*Technology In Support of the Environment.*

## V2C STANDARD FEATURES

* "QUIET RUN" PACKAGE
* FIRE CONTROL SYSTEM
* INPUT FLAME ARRESTER
* AUTO SHUT DOWN
  - High Water Temperature
  - High Oil Temperature
  - Low Oil Level
* AUTOMATIC OIL LEVEL REGULATOR
* WELL GAS FLOW METER
* EASILY TRANSPORTED - ONE MAN SETUP
* SHUTDOWN/CALL-UP CAPABILITY
* PERMITTABILITY IN SCAQMD
  - Soil Remediation (Various Locations)
* 20 MINUTE INSTALLATION CAPABILITY
* SLIDE IN/SLIDE OUT ENGINE PACKAGE
* PERMANENT STAND OR TRANSPORTABILITY
* 15' X 1 1/2" INTERNALLY GROUNDED VAPOR HOSE
* 50' STATIC REEL
* LCD MONITOR W/16 ITEM READOUT & DISC DRIVE
  - For Report Accumulation
* INVERTER PACKAGE
  - For "Stand Alone" Capability

## AVAILABLE OPTIONS

* MONITORING BY MODEM
* KIT FOR NATURAL GAS OPERATION

10/19/93

2.05 ON-BOARD COMPUTER CONTROL

The system shall include a "State of the Art" Data Acquisition System for monitoring the engine control.

2.06 MONITORING

Monitoring shall include a 16 channel data reporting system on engine vital signs and operation. Reporting can be on regular intervals (every hour or half hour) or manually at the discretion of the operator, or stored (30 days max.) for future retrieval. Remote monitoring by hardwire or cellular shall also be available.

2.07 WELL GAS FILTER

The system shall include a Well Gas Filter and moisture knock out. A Transducer shall be included to indicate well gas vacuum levels.

2.08 EXHAUST SYSTEM

The Exhaust System shall include a dual NOx reduction monolith and a dual HC/CO monolith. The oxygen supply to the NOx reduction unit shall be controlled at all times at 0.5% to 0.7% as read by an $O_2$ sensor in the exhaust manifold.

2.09 QUIET RUN

The system shall be capable of operating at a noise level of 55db measured at 10 meters without additional noise screening.

3.00 OPERATION

The operation of the system shall be automatic (except for start up, shut down and RPM set point) and shall not require manual adjustment of influent gas, supplemental fuel or combustion air.

4.00 CAPACITIES

4.01 VACUUM AND FLOW

The system shall be capable of developing up to 18" Hg at the well gas inlet. Flow rates shall be from 0 to 65 CFM. These conditions will depend on soil conditions, hydrocarbon concentrations and level of inerts encountered.

4.02 HYDROCARBON REMOVAL

The system shall be capable of removing up to 15 lbs/hr of hydrocarbons at a total destruction efficiency of 99.97%.

5.00 SAFETY FEATURES

7.00 GENERAL APPROVAL

The system shall have an approval by a registered third party testing laboratory for safety and operations.

8.00 WARRANTY

The system shall carry a one-year warranty on all items manufactured by the seller and the seller will pass on the guarantee of the manufacturer of purchased parts installed on the unit.

9.00 MANUFACTURE

The unit shall be manufactured in the United States of America and the supplier shall hold the owner. and/or its various departments free and harmless from any patent infringement suit arising out of the purchase of this Soil Venting System.

VR systems inc.

*Technology In Support of the Environment.*

# SPECIFICATIONS - MODEL V4

## 1.00 GENERAL

It is the intent of these specifications to describe a "State of the Art" Soil Remediation and Tank Degassing System including internal combustion engines capable of extracting hydrocarbon vapors from contaminated soil or storage tanks without the use of a compressor or pump, and destruct such vapors as fuel in a controlled manner by the use of an on-board computer system.

## 2.00 DETAILED DESCRIPTION

System shall conform to the following minimum requirements:

## 2.01 ENGINE

These VR Systems engines have been re-configured to design specification exclusive to VR Systems Vapor Extraction Equipment using a Ford Motor Company 460 C.I.D. engine block, heads and accessories. The engine shall be totally controlled by the computer system described below and shall be capable of operating one month without need of servicing. The engine shall be equipped with an automatic oil level device together with three (3) automotive type cartridge filters. The engine serves as both a vacuum pump and as a means of destroying hydrocarbon vapors removed from the soil. Engine cooling shall be by means of an oversized radiator and zero-pressure coolant system to insure safety and long life.

## 2.02 FUEL CONTROL SYSTEM

Supplemental fuel, as may be required for proper combustion, shall be either Propane (LPG) or Natural Gas. The control of the fuel to the engine shall be by the means of an electro/mechanical system including a Master Control Unit (MCU). The MCU shall adjust the supplemental fuel flow to compensate for changing influent hydrocarbon concentrations and maintain an air/fuel ratio at stoichiometric.

## 2.03 IGNITION SYSTEM

The Ignition System shall be an electronic type, automatically adjusted by commands from the computer.

## 2.04 ELECTRICAL POWER

Not required.

## 2.05 ON-BOARD COMPUTER CONTROL

The system shall include a "State of the Art" Data Acquisition System for monitoring and engine control.

5.02 FLAME ARRESTER

A 3" Flame Arrester shall be included to protect the well gas source from any "Flash Back" from the engine.

5.03 GROUNDING

A 50' Static Line and Reel shall be included.

5.04 AUTOMATIC ENGINE SHUT DOWN

The system shall be protected by automatic shut down under the following conditions:

Overspeed
High Coolant Temperature
High Oil Temperature
Low Oil Pressure
Fire
High Water Level (Well Gas Filter)

The computer shall be programmed to store and report the reason for the automatic engine shut down.

5.05 FUEL SHUT OFF

Means shall be included to shut off the fuel supply should the engine shut down for any reason.

5.06 LABEL AND INSTRUCTIONS

An Operation and Maintenance Manual shall be included establishing safe operation and required maintenance together with pertinent Material Safety Data Sheets from various suppliers. Safety and warning labels shall be appropriately affixed to the unit according to accepted standards. Safety and Operation instructions shall be conspicuously posted at the operation console within easy view of the operator.

6.00 TRANSPORTATION AND INSTALLATION

Included as part of the package shall be a transporter to safely move the unit from one site to another. Also, a stand shall be available and means supplied to slide the unit off of the transporter and onto the stand (and vice versa).

7.00 GENERAL APPROVAL

The system shall have an approval by a registered third party testing laboratory for safety and operations.

8.00 WARRANTY

The system shall carry a one-year warranty on all items manufactured by the sellers and the seller will pass on the guarantee of the manufacturer of purchased parts installed on the unit.

# APPENDIX C

## HOSPITAL MAP

# Installation Restoration Program

COPY FOR YOUR INFORMATION

# Facsimile Cover Sheet

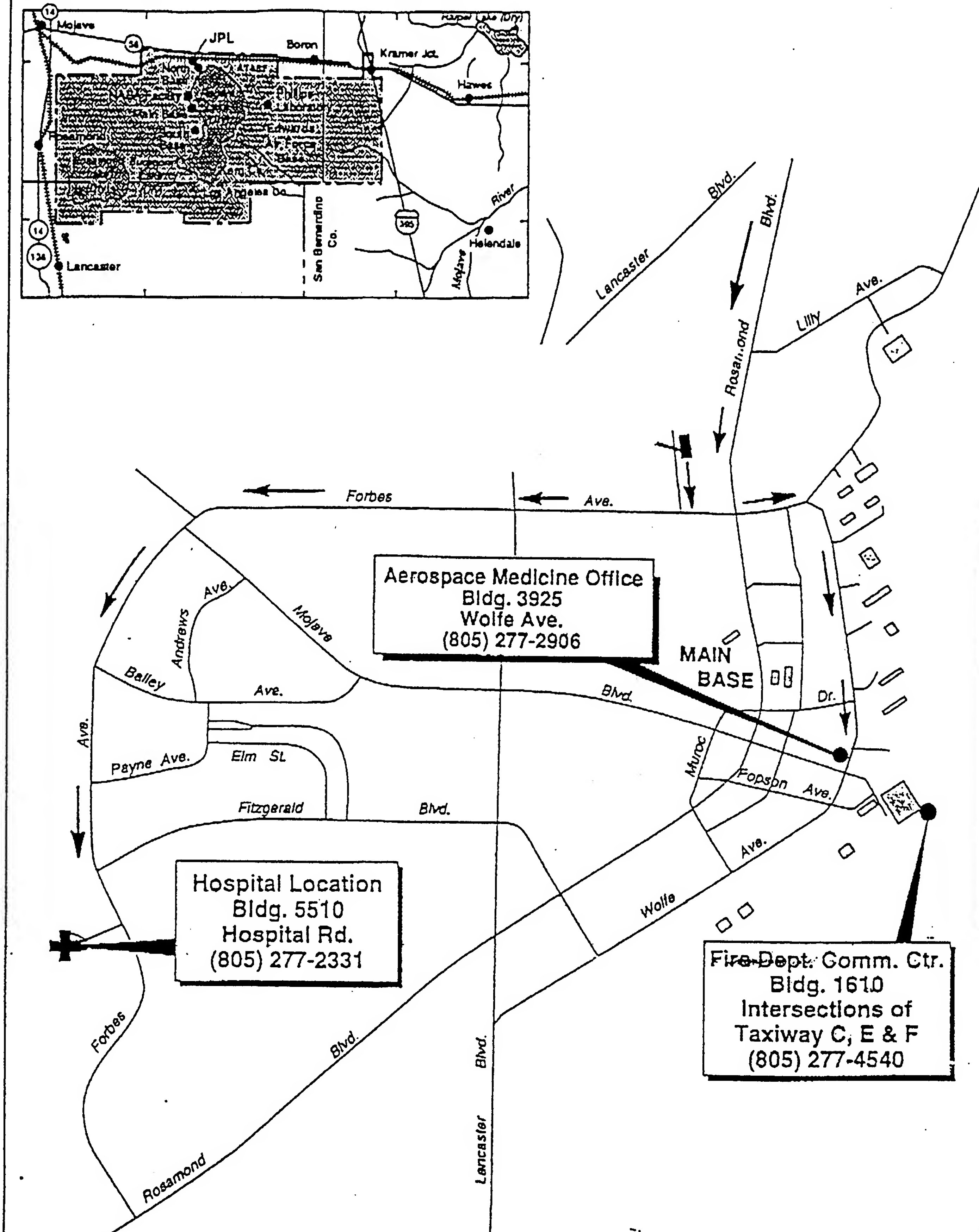
| | |
|---|---|
| **To:** | Mr. Patrick Haas |
| **Company:** | AFCEE / EST |
| **Phone:** | 240-4314 |
| **Fax:** | 240-4330 |
| **From:** | DAVID STECKEL |
| **Company:** | AFFTC / EMRR |
| **Phone:** | 537-1416 |
| **Fax:** | 537-6145 |
| **Date:** | 04/12/95 |
| **Number of Pages (incld cover):** | 3 |

**Contents:** The following are the requested emergency telephone numbers, along with a hospital location map for use in the Bioslurp Work Plan and HASP. If any further information is required, please feel free to contact me. Thank you.

David

# EMERGENCY TELEPHONE NUMBERS

| | |
|---|---|
| FOR ALL EMERGENCIES | 911 |
| LOCAL FIRE DEPARTMENT (COMMUNICATION CENTER) | (805) 277-4540 |
| FLIGHT MEDICINE (AMBULANCE) | (805) 277-2575 |
| SECURITY POLICE | (805) 277-2000 |
| IMMEDIATE MEDICAL CARE<br>EMERGENCY ROOM<br>AIR FORCE MATERIAL COMMAND<br>EDWARDS AFB<br>5500 HOSPITAL ROAD | (805) 277-2331 |
| REGIONAL MEDICAL CARE<br>EMERGENCY ROOM<br>ANTELOPE VALLEY HOSPITAL<br>15TH STREET WEST<br>LANCASTER, CA | (805) 949-5000 |
| REGIONAL POISON CONTROL<br>POISON INFORMATION AVAILABLE AT<br>LOS ANGELES COUNTY MEDICAL ASSOCIATION | (805) 484-5151 |
| EDWARDS AFB: ED FLETCHER AFFTC/SEG | (805) 277-8565 |
| EDWARDS AFB: MILITARY PUBLIC HEALTH | (805) 277-4238 |
| EDWARDS AFB: AEROSPACE MEDICINE (FLIGHT SURGEONS OFFICE) | (805) 277-2920 |
| PROGRAM CONTACTS | |
| AIR FORCE: DAVID STECKEL | (805) 277-1416 |




**Hospital Location Map**
**(Main Base Cantonment Area)**

Source: Base map from U.S.G.S. 7.5 minute Quadrangle, 1972, edited 1992.

# APPENDIX B

# LABORATORY ANALYTICAL REPORTS

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

# ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6122
Attn: Jeff Kittell

Sampled: 10/19/95   Received: 10/24/95   Analyzed: 10/27-28/95

Matrix: [ X ] Soil   [ ] Water   [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Extractable Quantitated As Diesel
BTXE - Benzene,Toluene,Xylenes,Ethylbenzene

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTXE - EPA Method 624/8240

## TPH/BTXE Results:

| Client ID/ Lab ID | Parameter | Concentration | Detection Limit | |
|---|---|---|---|---|
| MPC 3-6 | TPH * | 970 | 10 | mg/Kg |
| Comp 1 | Benzene | ND | 70 | ug/Kg |
| /BMI102495-02 | Toluene | ND | 70 | ug/Kg |
| | Total Xylenes | 590 | 70 | ug/Kg |
| | Ethylbenzene | 73 | 70 | ug/Kg |
| MPC 3-6 | TPH * | 460 | 10 | mg/Kg |
| Comp 2 | Benzene | ND | 50 | ug/Kg |
| /BMI102495-03 | Toluene | ND | 50 | ug/Kg |
| | Total Xylenes | 320 | 50 | ug/Kg |
| | Ethylbenzene | 55 | 50 | ug/Kg |

* - Components are in the range of jet fuel, diesel #1, diesel #2, light oil and motor oil.

Note: Hydrocarbons outside the range of diesel may have varying recoveries.

ND - Not Detected

Approved By: Roger L. Scholl   Date: 11/2/95
Roger L. Scholl, Ph.D.
Laboratory Director

Laboratory
Analysis Report

Sierra
Environmental
Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 11/16/95
Client : ALP-855
Taken by: CLIENT
Report : 14753
PO# :



| Sample | Collected Date | Time | MOISTURE CONTENT % | PARTICLE SIZE CLASSIF. HYDROMETER | DENSITY G/CM3 | POROSITY % | | |
|---|---|---|---|---|---|---|---|---|
| BMI102495-02 - MPC 3-6 COMP 1 | 10/19/95 | : | 8.6 | YES | 0.82 | 69.0 | | |
| BMI102495-03 - MPC 3-6 COMP 2 | 10/19/95 | : | 10.6 | YES | 0.74 | 72.0 | | |

Approved By:



William F. Pillsbury
*President*

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
*Manager*

Sierra
Environmental
Monitoring, Inc.

November 16, 1995

**TO:** **Alpha Analytical**

**FROM:** Sierra Environmental Monitoring, Inc.

**RE:** Particle Size Distribution Analysis for Samples:

SEM 9510-0728 AAI BMI102495-02
SEM 9502-0729 AAI BMI102495-03

As per your request, we have performed particle size analysis on the samples submitted to our laboratory. Test results are as follows:

| | 9510-0728 | 9510-0729 |
|---|---|---|
| % Sand | 83.0 | 72.6 |
| % Silt | 5.4 | 17.3 |
| % Clay | 11.6 | 10.1 |

The sample was passed through a #10 sieve prior to analysis as per procedure. All results are based on oven dry sample weights.

We appreciate this opportunity to provide our laboratory testing services. If you have any questions or require further testing, please feel free to contact us at your convenience.

Sincerely,
**SIERRA ENVIRONMENTAL MONITORING, INC.**

John Seher
Laboratory Manager

William F. Pillsbury
*President*

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
*Manager*

Battelle
Columbus Laboratories

614 424 6122

## CHAIN OF CUSTODY RECORD

Form No. 1

Proj. No. G462201-30D0201

Project Title: EDWARDS AFB

SAMPLERS: (Signature) [signature]

| DATE | TIME | SAMPLE I.D. | PARTICLE SIZE DISTRIBUTION | BULK DENSITY | POROSITY | MOISTURE CONTENT | BENZENE | TOLUENE | ETHYLBENZENE | XYLENE | TPH | | | | | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/19/95 | 0800 | MPC 3-6 COMP 1 | X | ✓ | ✓ | ✓ | ✓ | X | X | X | ✓ | | | | | 1 | 1 | |
| " | 0800 | MPC 3-6 COMP 1 | X | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X | | | | | 1 | 1 | |
| " | 0800 | MPC 3-6 COMP 1 | ✓ | Y | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | 1 | 1 | |
| " | 0805 | MPC 3-6 COMP 2 | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | ✓ | X | | | | | 1 | 1 | |
| " | 0805 | MPC 3-6 COMP 2 | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | 1 | 1 | |
| " | 0805 | MPC 3-6 COMP ~~B2~~ | Y | Y | ✓ | ✓ | X | ✓ | ✓ | ✓ | Y | | | | | 1 | 1 | |

per Jeff

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| [signature] | 10/22/95 0941 | | | | |
| **Relinquished by: (Signature)** | **Date/Time** | **Received by: (Signature)** | **Relinquished by: (Signature)** | **Date/Time** | **Received by: (Signature)** |
| | | | | | |
| **Relinquished by: (Signature)** | **Date/Time** | **Received for Laboratory by: (Signature)** | **Date/Time** | **Remarks** | |
| | | [signature] | 10/24/95 1030 | SEND RESULTS TO: JEFF KITTEL 505 KING AVE. 614 424 6199 | |

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

**Billing Information:**

Name
Address
City, State, Zip
Phone Number

Page # 1 of 1

Client Name: Battelle
Address:
City, State, Zip:
P.O. #:
Phone #: (614) 424-6122
Report Attention: Jeff Kittell
Sampled by: Client

| Time Sampled | Date Sampled | Type* See Key Below | Lab ID Number | Sample Description | Number of Containers | TPH | BTXE | Inorg. | [illegible] | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10/19 | SO | BMI102495 02 | MPC 3-6 Comp 1 | 3 | X | X | X | | | | | | Composite |
| | ✓ | ✓ | 03 | MPC 3-6 Comp 2 | 3 | X | X | X | | | | | | Composite |

| | Signature | Print Name | Company | Date | Time |
|---|---|---|---|---|---|
| Relinquished by | | | | | |
| Received by | [signature] | Linda Lerner | AAI | 10/24/95 | 1030 |
| Relinquished by | Bruce Arya | BRUCE Arya | API | 10/25/95 | 14:10 |
| Received by | [signature] | [signature] | SCM | 10/25/95 | 1410 |
| Relinquished by | | | | | |
| Received by | | | | | |

**NOTE:** Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other

**Alpha Analytical, Inc.**
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

# ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: 91221
Phone: (614) 424-6122
Attn: Jeff Kittell

Sampled: 10/21/95    Received: 10/24/95    Analyzed: 10/27-11/01/95

Matrix: [ ] Soil    [ X ] Water    [ ] Waste

Analysis Requested: TPH (Diesel) - Total Petroleum Hydrocarbons- Extractable Quantitated As Diesel
TPH (Gasoline) - Total Petroleum Hydrocarbons- Purgeable Quantitated As Gasoline
BTXE -Benzene,Toluene,Xylenes,Ethylbenzene

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTXE - EPA Method 624/8240

## TPH/BTXE Results:

| Client ID/ Lab ID | Parameter | Concentration | Detection Limit | |
|---|---|---|---|---|
| EAFB-W1 /BMI102495-04 | TPH (Diesel)* | 11 | 5.0 | mg/L |
| | TPH (Gasoline) | 13 | 5.0 | mg/L |
| | Benzene | 690 | 10 | ug/L |
| | Toluene | 2,000 | 10 | ug/L |
| | Total Xylenes | 2,100 | 10 | ug/L |
| | Ethylbenzene | 370 | 10 | ug/L |
| EAFB-W2 /BMI102495-05 | TPH (Diesel)* | 11 | 5.0 | mg/L |
| | TPH (Gasoline) | 17 | 5.0 | mg/L |
| | Benzene | 690 | 10 | ug/L |
| | Toluene | 1,900 | 10 | ug/L |
| | Total Xylenes | 2,100 | 10 | ug/L |
| | Ethylbenzene | 370 | 10 | ug/L |
| EAFB-W3 /BMI102495-06 | TPH (Diesel)* | 10 | 5.0 | mg/L |
| | TPH (Gasoline) | 15 | 5.0 | mg/L |
| | Benzene | 700 | 10 | ug/L |
| | Toluene | 1,900 | 10 | ug/L |
| | Total Xylenes | 2,000 | 10 | ug/L |
| | Ethylbenzene | 360 | 10 | ug/L |

**Alpha Analytical, Inc.**
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

Continued:

| Client ID/ Lab ID | Parameter | Concentration | Detection Limit | |
|---|---|---|---|---|
| EAFB-W4 | TPH (Diesel)* | 10 | 5.0 | mg/L |
| /BMI102495-07 | TPH (Gasoline) | 16 | 5.0 | mg/L |
| | Benzene | 700 | 10 | ug/L |
| | Toluene | 1,800 | 10 | ug/L |
| | Total Xylenes | 1,900 | 10 | ug/L |
| | Ethylbenzene | 350 | 10 | ug/L |
| EAFB-W5 | TPH (Diesel)* | 10 | 5.0 | mg/L |
| /BMI102495-08 | TPH (Gasoline) | 14 | 5.0 | mg/L |
| | Benzene | 700 | 10 | ug/L |
| | Toluene | 1,800 | 10 | ug/L |
| | Total Xylenes | 2,000 | 10 | ug/L |
| | Ethylbenzene | 330 | 10 | ug/L |
| EAFB-W6 | TPH (Diesel)* | 11 | 5.0 | mg/L |
| /BMI102495-09 | TPH (Gasoline) | 16 | 5.0 | mg/L |
| | Benzene | 690 | 10 | ug/L |
| | Toluene | 1,900 | 10 | ug/L |
| | Total Xylenes | 2,000 | 10 | ug/L |
| | Ethylbenzene | 380 | 10 | ug/L |

* - Components are in the range of gasoline and jet fuel.

Note: Hydrocarbons outside the range of diesel may have varying recoveries.

ND - Not Detected

Approved By: Roger L. Scholl Date: 11/3/95
Roger L. Scholl, Ph.D.
Laboratory Director

Battelle
Columbus Laboratories

# CHAIN OF CUSTODY RECORD

Form No. 1

**Proj. No.** G 462701-30DC201

**Project Title** EDWARDS AFB

**SAMPLERS: (Signature)** [signature]

| DATE | TIME | SAMPLE I.D. | TPH | BTEX | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|
| 11/21/95 | 1250 | EAFB - W1 | X | X | 1 | 1 | |
| " | " | EAFB - W2 | X | X | 1 | 1 | WATER SAMPLE |
| " | " | EAFB - W3 | X | X | 1 | 1 | |
| " | " | EAFB - W4 | X | X | 1 | 1 | |
| " | " | EAFB - W5 | X | X | 1 | 1 | REFERENCE |
| " | " | EAFB - W6 | X | X | 1 | 1 | P.O. # 91221 |

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| [signature] | 10/21/95 1308 | | | | |

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| | | | | | |

| Relinquished by: (Signature) | Date/Time | Received for Laboratory by: (Signature) | Date/Time | Remarks |
|---|---|---|---|---|
| | | [signature] | 10/24/95 1030 | SEND. RESULTS TO: JEFF KITTEL 505 KING AVE. COLUMBUS OHIO 43201 |

Page 1 of 1

Billing Information:
Name
Address
City, State, Zip
Phone Number


Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406




Client Name Battelle
P.O. # 91221
Address
Phone #
City, State, Zip
Report Attention Jeff Kittel
Sampled by Clint

| Time Sampled | Date Sampled | Type* See Key Below | Lab ID Number | Sample Description | Number of Containers | TPH | BTXE | Remarks |
|---|---|---|---|---|---|---|---|---|
| | 10/21 | AQ | BMI102495-04 | EAFB-W1 | 1 | X | X | 2 - 40ml VOA each. |
| | ↓ | ↓ | 05 | EAFB-W2 | 1 | X | X | |
| | | | 06 | EAFB-W3 | 1 | X | X | |
| | | | 07 | EAFB-W4 | 1 | X | X | |
| | | | 08 | EAFB-W5 | 1 | X | X | |
| | | | 09 | EAFB-W6 | 1 | X | X | |

| | Signature | Print Name | Company | Date | Time |
|---|---|---|---|---|---|
| Relinquished by | | | | | |
| Received by | [signature] | Linda Lerner | AAI | 10/24/95 | 1020 |
| Relinquished by | | | | | |
| Received by | | | | | |
| Relinquished by | | | | | |
| Received by | | | | | |

**NOTE:** Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other

# @ AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

## WORK ORDER #: 9510273

Work Order Summary

**CLIENT:** Mr. Jeff Kittel
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

**BILL TO:** Same

**PHONE:** 614-424-6122
**FAX:** 614-424-3667
**DATE RECEIVED:** 10/24/95
**DATE COMPLETED:** 10/30/95

**INVOICE #** 8470
**P.O. #** 91227
**PROJECT #** G462201-30D0201 Edwards AFB
**AMOUNT$:** $692.98

| FRACTION # | NAME | TEST | RECEIPT VAC./PRES. | PRICE |
|---|---|---|---|---|
| 01A | EAFB-A1 | TO-3 | 3.5 "Hg | $120.00 |
| 02A | EAFB-A2 | TO-3 | 4.0 "Hg | $120.00 |
| 02B | EAFB-A2 Duplicate | TO-3 | 4.0 "Hg | NC |
| 03A | EAFB-A3 | TO-3 | 3.5 "Hg | $120.00 |
| 04A | EAFB-A4 | TO-3 | 2.5 "Hg | $120.00 |
| 05A | EAFB-A5 | TO-3 | 2.5 "Hg | $120.00 |
| 06A | Method Spike | TO-3 | NA | NC |
| 07A | Lab Blank | TO-3 | NA | NC |

| | | |
|---|---|---|
| Misc. Charges | 1 Liter Summa Canister Preparation (5) @ $10.00 each. | $50.00 |
| | Shipping (10/11/95) | $42.98 |

CERTIFIED BY: Linda L. Freeman
Laboratory Director

DATE: 10/30/95

180 BLUE RAVINE ROAD, SUITE B FOLSOM, CA 95630
(916) 985-1000 • (800) 985-5955 • FAX (916) 985-1020

# AIR TOXICS LTD.

SAMPLE NAME: EAFB-A1

ID#: 9510273-01A

**EPA METHOD TO-3**

(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102612 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 95 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| Benzene | 0.095 | 0.31 | 14 | 45 |
| Toluene | 0.095 | 0.36 | 13 | 50 |
| Ethyl Benzene | 0.095 | 0.42 | 7.6 | 34 |
| Total Xylenes | 0.095 | 0.42 | 32 | 140 |

**TOTAL PETROLEUM HYDROCARBONS**

**GC/FID**

(Quantitated as Jet Fuel)

| File Name: | 6102612 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 95 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| TPH* (C5+ Hydrocarbons) | 0.95 | 6.2 | 1800 | 12000 |
| C2 - C4** Hydrocarbons | 0.95 | 1.7 | 400 | 730 |

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: 1 Liter Summa Canister**

# AIR TOXICS LTD.

SAMPLE NAME: EAFB-A2
ID#: 9510273-02A

**EPA METHOD TO-3**
(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102615 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 1200 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| Benzene | 1.2 | 3.9 | 170 | 550 |
| Toluene | 1.2 | 4.6 | 330 | 1300 |
| Ethyl Benzene | 1.2 | 5.3 | 100 | 440 |
| Total Xylenes | 1.2 | 5.3 | 420 | 1800 |

**TOTAL PETROLEUM HYDROCARBONS**
**GC/FID**
(Quantitated as Jet Fuel)

| File Name: | 6102615 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 1200 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| TPH* (C5+ Hydrocarbons) | 12 | 78 | 26000 | 170000 |
| C2 - C4** Hydrocarbons | 12 | 22 | 730 | 1300 |

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: 1 Liter Summa Canister**

# AIR TOXICS LTD.

SAMPLE NAME: EAFB-A2 Duplicate
ID#: 9510273-02B

**EPA METHOD TO-3**
(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102614 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 1200 | | Date of Analysis: 10/26/95 | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| Benzene | 1.2 | 3.9 | 180 | 580 |
| Toluene | 1.2 | 4.6 | 390 | 1500 |
| Ethyl Benzene | 1.2 | 5.3 | 110 | 480 |
| Total Xylenes | 1.2 | 5.3 | 450 | 2000 |

**TOTAL PETROLEUM HYDROCARBONS**
**GC/FID**
(Quantitated as Jet Fuel)

| File Name: | 6102614 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 1200 | | Date of Analysis: 10/26/95 | |
| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | Amount (ppmv) | Amount (uG/L) |
| TPH* (C5+ Hydrocarbons) | 12 | 78 | 29000 | 190000 |
| C2 - C4** Hydrocarbons | 12 | 22 | 820 | 1500 |

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: 1 Liter Summa Canister**

# AIR TOXICS LTD.

SAMPLE NAME: EAFB-A3

ID#: 9510273-03A

**EPA METHOD TO-3**

(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102616 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 82 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| Benzene | 0.082 | 0.27 | 0.12 | 0.39 |
| Toluene | 0.082 | 0.31 | 3.2 | 12 |
| Ethyl Benzene | 0.082 | 0.36 | 5.5 | 24 |
| Total Xylenes | 0.082 | 0.36 | 26 | 110 |

**TOTAL PETROLEUM HYDROCARBONS**

**GC/FID**

(Quantitated as Jet Fuel)

| File Name: | 6102616 | | Date of Collection: 10/21/95 | |
|---|---|---|---|---|
| Dil. Factor: | 82 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| TPH* (C5+ Hydrocarbons) | 0.82 | 5.3 | 1300 | 8400 |
| C2 - C4** Hydrocarbons | 0.82 | 1.5 | Not Detected | Not Detected |

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: 1 Liter Summa Canister**

# AIR TOXICS LTD.

SAMPLE NAME: EAFB-A4

ID#: 9510273-04A

**EPA METHOD TO-3**

(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102617 | | Date of Collection: 10/22/95 | |
|---|---|---|---|---|
| Dil. Factor: | 22 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| Benzene | 0.022 | 0.071 | 8.6 | 28 |
| Toluene | 0.022 | 0.084 | 0.98 | 3.8 |
| Ethyl Benzene | 0.022 | 0.097 | Not Detected | Not Detected |
| Total Xylenes | 0.022 | 0.097 | 0.11 | 0.48 |

**TOTAL PETROLEUM HYDROCARBONS**

**GC/FID**

(Quantitated as Jet Fuel)

| File Name: | 6102617 | | Date of Collection: 10/22/95 | |
|---|---|---|---|---|
| Dil. Factor: | 22 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| TPH* (C5+ Hydrocarbons) | 0.22 | 1.4 | 260 | 1700 |
| C2 - C4** Hydrocarbons | 0.22 | 0.40 | 24 | 44 |

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: 1 Liter Summa Canister**

# AIR TOXICS LTD.

SAMPLE NAME: EAFB-A5

ID#: 9510273-05A

**EPA METHOD TO-3**

(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102618 | | Date of Collection: 10/22/95 | |
|---|---|---|---|---|
| Dil. Factor: | 2.2 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| Benzene | 0.002 | 0.007 | Not Detected | Not Detected |
| Toluene | 0.002 | 0.008 | Not Detected | Not Detected |
| Ethyl Benzene | 0.002 | 0.010 | Not Detected | Not Detected |
| Total Xylenes | 0.002 | 0.010 | Not Detected | Not Detected |

**TOTAL PETROLEUM HYDROCARBONS**

**GC/FID**

(Quantitated as Jet Fuel)

| File Name: | 6102618 | | Date of Collection: 10/22/95 | |
|---|---|---|---|---|
| Dil. Factor: | 2.2 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| TPH* (C5+ Hydrocarbons) | 0.022 | 0.14 | 0.58 | 3.8 |
| C2 - C4** Hydrocarbons | 0.022 | 0.040 | Not Detected | Not Detected |

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: 1 Liter Summa Canister**

# AIR TOXICS LTD.

SAMPLE NAME: Method Spike

ID#: 9510273-06A

**EPA METHOD TO-3**

(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102603 | | Date of Collection: NA |
|---|---|---|---|
| Dil. Factor: | 1.0 | | Date of Analysis: 10/26/95 |

| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | % Recovery |
|---|---|---|---|
| Benzene | 0.001 | 0.003 | 84 |
| Toluene | 0.001 | 0.004 | 80 |
| Ethyl Benzene | 0.001 | 0.004 | 74 |
| Total Xylenes | 0.001 | 0.004 | 82 |

**TOTAL PETROLEUM HYDROCARBONS**

**GC/FID**

(Quantitated as Jet Fuel)

| File Name: | 6102605 | | Date of Collection: NA |
|---|---|---|---|
| Dil. Factor: | 1.0 | | Date of Analysis: 10/26/95 |

| Compound | Det. Limit (ppmv) | Det. Limit (uG/L) | % Recovery |
|---|---|---|---|
| TPH* (C5+ Hydrocarbons) | 0.010 | 0.065 | 117 |
| C2 - C4** Hydrocarbons | 0.010 | 0.018 | 117 |

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: NA**

# AIR TOXICS LTD.

SAMPLE NAME: Lab Blank

ID#: 9510273-07A

**EPA METHOD TO-3**

(Aromatic Volatile Organics in Air)

**GC/PID**

| File Name: | 6102606 | | Date of Collection: NA | |
|---|---|---|---|---|
| Dil. Factor: | 1.0 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| Benzene | 0.001 | 0.003 | Not Detected | Not Detected |
| Toluene | 0.001 | 0.004 | Not Detected | Not Detected |
| Ethyl Benzene | 0.001 | 0.004 | Not Detected | Not Detected |
| Total Xylenes | 0.001 | 0.004 | Not Detected | Not Detected |

**TOTAL PETROLEUM HYDROCARBONS**

**GC/FID**

(Quantitated as Jet Fuel)

| File Name: | 6102606 | | Date of Collection: NA | |
|---|---|---|---|---|
| Dil. Factor: | 1.0 | | Date of Analysis: 10/26/95 | |
| **Compound** | **Det. Limit (ppmv)** | **Det. Limit (uG/L)** | **Amount (ppmv)** | **Amount (uG/L)** |
| TPH* (C5+ Hydrocarbons) | 0.010 | 0.065 | Not Detected | Not Detected |
| C2 - C4** Hydrocarbons | 0.010 | 0.018 | Not Detected | Not Detected |

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

**Container Type: NA**

AIR TOXICS LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY
180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

# CHAIN-OF-CUSTODY RECORD

№ 006236



Contact Person JEFF KITTEL
Company BATTELLE
Address 505 KING AVE. City COLUMBUS State OH Zip 43201
Phone 614-424-6122 FAX 614-424-3667
**Collected By:** Signature Mike Woolf

**Project info:**
P.O. # 91227
Project # G46220I-30D0201
Project Name EDWARDS AFB

**Turn Around Time:**
☒ Normal
☐ Rush ____ Specify

| Lab I.D. | Field Sample I.D. | Date & Time | Analyses Requested | Canister Pressure / Vacuum Initial | Final | Receipt |
|---|---|---|---|---|---|---|
| 01A | EAFB-A1 | 10-21-95 | BTEX, TPH | 28" Hg | 0 | 3.5" Hg |
| 02A/B | EAFB-A2 | 10-21-95 | BTEX, TPH | 28" | 0 | 4.0" Hg |
| 03A | EAFB-A3 | 10-21-95 | BTEX, TPH | 28" | 0 | 3.5" Hg |
| 04A | EAFB-A4 | 10-22-95 | BETX, TPH | 28" | 0 | 2.5" Hg |
| 05A | EAFB-A5 | 10-22-95 | BTEX, TPH | 28" | 0 | 2.5" Hg |
| | | | | | | 10/24/95 |

**Relinquished By:** (Signature) Date/Time Tom T. Easter 10/22/95 Print Name TOM T. EASTER
Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time
Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time AIR 10/24/95 900

Notes: SEND RESULTS TO: JEFF KITTEL (ABOVE)

| Lab Use Only | Shipper Name | Air Bill # | Opened By: | Date/Time | Temp. (°C) | Condition | Custody Seals Intact? | Work Order # |
|---|---|---|---|---|---|---|---|---|
| | Fed-X | 7221940180 | TS | 10/24/95 900 | Ambient | Good | Yes No (None) N/A | 9510273 |

Form 1293 rev. 06

Battelle
Columbus Laboratories

Form No. 1

# CHAIN OF CUSTODY RECORD

**Proj. No.** 11673211-31DI201

**Project Title** EDWARDS AFB

**SAMPLERS: (Signature)** [signature]

| DATE | TIME | SAMPLE I.D. | TPH | BTEX | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|
| 11/21/95 | 1250 | EAFB - W1 | X | X | 1 | 1 | [illegible] |
| " | " | EAFB - W2 | X | X | 1 | 1 | |
| " | " | EAFB - W3 | X | X | 1 | 1 | |
| " | " | EAFB - W4 | X | X | 1 | 1 | [illegible] |
| " | " | EAFB - W5 | X | X | 1 | 1 | [illegible] 91221 |
| " | " | EAFB - W6 | X | X | | | |

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| [signature] | 11/21/95 1308 | | | | |
| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
| | | | | | |
| Relinquished by: (Signature) | Date/Time | Received for Laboratory by: (Signature) | Date/Time | Remarks: Send results to: Jeff Kittel, 505 King Ave., Columbus, OH 43201 | |

Page 1 of 1

Battelle
Columbus Laboratories

# CHAIN OF CUSTODY RECORD

Form No. /

Proj. No. G462201-30D0201

Project Title: EDWARDS AFB

SAMPLERS: (Signature) [signature]

| DATE | TIME | SAMPLE I.D. | Particle size distribution | Bulk density | Porosity | Moisture content | Benzene | Toluene | Ethylbenzene | Xylene | TPH | | | | | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/19/95 | 0800 | MPC 3-6 COMP 1 | X | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | | / | / | |
| " | 0800 | MPC 3-6 COMP 1 | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | | | | / | / | |
| " | 0800 | MPC 3-6 COMP 1 | ✓ | ✓ | | ✓ | | | | ✓ | | | | | | / | / | |
| " | 0805 | MPC 3-6 COMP 2 | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | | | | | / | / | |
| " | 0805 | MPC 3-6 COMP 2 | ✓ | ✓ | | ✓ | ✓ | | | ✓ | | | | | | / | / | |
| " | 0805 | MPC 3-6 COMP 3 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | / | / | |

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| [signature] | 11/22/95 0900 | | | | |
| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
| | | | | | |
| Relinquished by: (Signature) | Date/Time | Received for Laboratory by: (Signature) | Date/Time | Remarks [illegible] | |

Page / of /

**Battelle**
Columbus Laboratories

## CHAIN OF CUSTODY RECORD

Form No. 1 of 1

| Proj. No. | Project Title |
|---|---|
| C4U1201-3UD0201 | EDWARDS AFB |

SAMPLERS: (Signature) [signature]

| DATE | TIME | SAMPLE I.D. | BOILING POINT DISTRIBUTION | BTEX | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|
| 10/21/95 | 1302 | EAFB-F1 | X | X | 1 | 1 | JP-4 FUEL SAMPLE REFERENCE P.O. # 9122 |

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| [signature] | 10/21/95 1302 | | | | |
| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
| | | | | | |
| Relinquished by: (Signature) | Date/Time | Received for Laboratory by: (Signature) | Date/Time | Remarks | |
| | | | | [illegible] | |

Page 1 of 1

# AIR TOXICS LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY

180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

## CHAIN-OF-CUSTODY RECORD

№ 008236

Page 1 of 1

Contact Person JEFF KITTEL ~~EE~~
Company BATTELLE
Address 505 KING AVE. City COLUMBUS State OH Zip 43201
Phone 614-424-6122 FAX 614-424-3667
Collected By: Signature Mike Woolf

**Project info:**
P.O. # 91227
Project # G46270-30D0201
Project Name EDWARDS AFB

**Turn Around Time:**
☒ Normal
☐ Rush ______ Specify

| Lab I.D. | Field Sample I.D. | Date & Time | Analyses Requested | Canister Pressure / Vacuum Initial | Final | Receipt |
|---|---|---|---|---|---|---|
| | EAFB-A1 | 10-21-95 | BTEX, TPH | 28" Hg | 0 | |
| | EAFB-A2 | 10-21-95 | BTEX, TPH | 28" | 0 | |
| | EAFB-A3 | 10-21-95 | BTEX, TPH | 28" | 0 | |
| | EAFB-A4 | 10-22-95 | BETX, TPH | 28" | 0 | |
| | EAFB-A5 | 10-22-95 | BTEX, TPH | 28" | 0 | |
| | | | | | | |
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| | | | | | | |
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**Relinquished By:** (Signature) Jon T. Eastep Date/Time 10/27/95 Print Name JON T. EASTEP
Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time
Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time

Notes: SEND RESULTS TO JEFF KITTEL (ABOVE)

| Lab Use Only | Shipper Name | Air Bill # | Opened By: | Date/Time | Temp. (°C) | Condition | Custody Seals Intact? | Work Order # |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Yes No None N/A | |

Form 1293 rev. 06

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

# ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30D0201
Phone: (614) 424-6122
Attn: Al Pollack

Alpha Analytical Number: BMI102495-01

Client I.D. Number: EAFB-F1

Date Sampled: 10/21/95

Date Received: 10/24/95

| Compound | Method | Concentration ug/Kg | Detection Limit ug/Kg | Date Analyzed |
|---|---|---|---|---|
| Benzene | 8240 | ND | 130,000 | 10/28/95 |
| Toluene | 8240 | 1,800,000 | 130,000 | 10/28/95 |
| Total Xylenes | 8240 | 8,200,000 | 130,000 | 10/28/95 |
| Ethylbenene | 8240 | 1,500,000 | 130,000 | 10/28/95 |
| C-range Compounds | Method | Percentage of Total | Detection Limit (Not Applicable) | Date Analyzed |
| C09< | GC/FID | 14.0 | NA | 11/07/95 |
| C10 | GC/FID | 14.4 | NA | 11/07/95 |
| C11 | GC/FID | 15.9 | NA | 11/07/95 |
| C12 | GC/FID | 16.1 | NA | 11/07/95 |
| C13 | GC/FID | 14.1 | NA | 11/07/95 |
| C14 | GC/FID | 10.1 | NA | 11/07/95 |
| C15 | GC/FID | 6.1 | NA | 11/07/95 |
| C16 | GC/FID | 3.4 | NA | 11/07/95 |
| C17> | GC/FID | 5.9 | NA | 11/07/95 |

Approved by: Roger L. Scholl

Roger L. Scholl, Ph.D.
Laboratory Director

Date: 11/8/95

**Battelle**
Columbus Laboratories

# CHAIN OF CUSTODY RECORD

Form No. 1 OF 1

| Proj. No. | Project Title | SAMPLE TYPE (√) | | | | | | | | | | | | | | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G41-2201-30D0201 | EDWARDS AFB | | | | | | | | | | | | | | | | | |

SAMPLERS: (Signature) [signature]

| DATE | TIME | SAMPLE I.D. | BOILING POINT DISTRIBUTION | BTEX | | | | | | | | | | | | Container No. | Number of Containers | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/21/95 | 1302 | EAFB-F1 | X | X | | | | | | | | | | | | 1 | 1 | JP-4 FUEL SAMPLE |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | REFERENCE P.O. # 91221 |

| Relinquished by: (Signature) | Date/Time | Received by: (Signature) | Relinquished by: (Signature) | Date/Time | Received by: (Signature) |
|---|---|---|---|---|---|
| [signature] | 10/21/95 1302 | | | | |
| **Relinquished by: (Signature)** | **Date/Time** | **Received by: (Signature)** | **Relinquished by: (Signature)** | **Date/Time** | **Received by: (Signature)** |
| | | | | | |
| **Relinquished by: (Signature)** | **Date/Time** | **Received for Laboratory by: (Signature)** | **Date/Time** | **Remarks** | |
| | | [signature] | 10/24/95 1020 | SEND RESULTS TO: JEFF KITTEL 505 KING AVE COLUMBUS, [illegible] 43[illegible] | |

Page 1 of 1

**Billing Information:**

Name

Address

City, State, Zip

Phone Number


**Alpha Analytical, Inc.**
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406


Page # 1 of 1

Client Name: Battelle

P.O. # 91221

Address

Phone #

City, State, Zip

Report Attention: Jeff Kittel

Sampled by

| Time Sampled | Date Sampled | Type* See Key Below | Lab ID Number | Sample Description | Number of Containers | BTXE | Boiling Pt. Dist. | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10/21 | OT | BMI102495-01 | EAFB-F1 | 1 | X | X | | | | | | | Small Tin Can |
| | | | | | | | | | | | | | | |
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| | Signature | Print Name | Company | Date | Time |
|---|---|---|---|---|---|
| Relinquished by | | | | | |
| Received by | [signature] | Linda Lerner | AAI | 10/24/95 | 1030 |
| Relinquished by | | | | | |
| Received by | | | | | |
| Relinquished by | | | | | |
| Received by | | | | | |

**NOTE:** Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other

NOV 08 '95 11:49 ALPHA ANALYTICAL

**Alpha Analytical, Inc.**
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

# ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30D0201
Phone: (614) 424-6122
Attn: Al Pollack

Alpha Analytical Number: BMI102495-01

Client I.D. Number: EAFB-F1

Date Sampled: 10/21/95

Date Received: 10/24/95

| Compound | Method | Concentration ug/Kg | Detection Limit ug/Kg | Date Analyzed |
|---|---|---|---|---|
| Benzene | 8240 | ND | 130,000 | 10/28/95 |
| Toluene | 8240 | 1,800,000 | 130,000 | 10/28/95 |
| Total Xylenes | 8240 | 8,200,000 | 130,000 | 10/28/95 |
| Ethylbenzene | 8240 | 1,500,000 | 130,000 | 10/28/95 |
| C-range Compounds | Method | Percentage of Total | Detection Limit (Not Applicable) | Date Analyzed |
| C09< | GC/FID | 14.0 | NA | 11/07/95 |
| C10 | GC/FID | 14.4 | NA | 11/07/95 |
| C11 | GC/FID | 15.9 | NA | 11/07/95 |
| C12 | GC/FID | 16.1 | NA | 11/07/95 |
| C13 | GC/FID | 14.1 | NA | 11/07/95 |
| C14 | GC/FID | 10.1 | NA | 11/07/95 |
| C15 | GC/FID | 6.1 | NA | 11/07/95 |
| C16 | GC/FID | 3.4 | NA | 11/07/95 |
| C17> | GC/FID | 5.9 | NA | 11/07/95 |

Approved by: Roger L. Scholl

Date: 11/8/95

Roger L. Scholl, Ph.D.
Laboratory Director

# APPENDIX C

# SYSTEM CHECKLIST

**Checklist for System Shakedown**

Site: EDWARDS, AFB CA.

Date: ______________

Operator's Initials: JTE

| Equipment | Check if Okay | Comments |
|---|---|---|
| Liquid Ring Pump | ✓ | |
| Aqueous Effluent Transfer Pump | ✓ | |
| Oil/Water Separator | ✓ | |
| Vapor Flowmeter | ✓ | |
| Fuel Flowmeter | ✓ | |
| Water Flowmeter | ✓ | |
| Emergency Shut off Float Switch<br>Effluent Transfer Tank | ✓ | |
| Analytical Field Instrumentation<br>GasTector™ $O_2/CO_2$ Analyzer<br>TraceTector™ Hydrocarbon Analyzer<br>Oil/Water Interface Probe<br>Magnehelic Boards<br>Thermocouple Thermometer | ✓ | |

**Figure 12. Bioslurper Pilot Test Shakedown Checklist**

# APPENDIX D

# DATA SHEETS FROM THE SHORT-TERM PILOT TEST

# ATMOSPHERIC OBSERVATIONS

Site: EDWARDS Operators: EASTEP/Woolfe

| Date/Time | Ambient Temperature | Relative Humidity | Barometric Pressure |
|---|---|---|---|
| 10/20/95 / 2050 | 77.8°F | 22% | 30.95" |
| 10/21 / 0600 | 72.8°F | 31% | 30.90" |
| 10/21 / 1011 | 84.2°F | 26% | 30.85" |
| 10/21 / 2037 | 75.6°F | 26% | 30.70" |
| 10/22 / 0956 | 66.8°F | 13% | 30.87" |
| 10/22 / 1510 | 71.2°F | 7% | 30.85" |
| 10/22 / 2030 | 64.7°F | 9% | 30.85" |
| 10/23 / 1325 | 65.7°F | 12% | 31.00" |
| 10/23 / 1500 | 76.7°F | 7% | 30.92" |
| 10/23 / 2138 | 57.7°F | 11% | 30.92" |
| 10/24 / 0916 | 52.3°F | 12% | 30.97" |
| 10/24 / 1431 | 75°F | 7% | 30.94" |
| 10/24 / 2000 | 72°F | 8% | 30.93" |
| 10/25 / 0845 | 57°F | 16% | 30.95" |
| 10/25 / 1200 | 66°F | 11% | 30.95" |
| 10/25 / 1530 | 76°F | 9% | 30.90" |
| 10/25 / 1900 | 66°F | 20% | 30.90" |
| 10/31 / 1730 | 58°F | 36% | 30.70" |
| 10/31 / 2130 | 58°F | 72% | 30.70" |

## Baildown Test Record Sheet

Site: EDWARDS AFB

Well Identification: 24

Well Diameter (OD/ID): 4" ID

Date at Start of Test: 10/16/95

Sampler's Initials: EASTEP/woolfc

Time at Start of Test: 1552 HRS

Initial Readings

| Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) | Total Volume Bailed (L |
|---|---|---|---|
| 26.55' | 21.5' | 5.05' | |

Test Data

| Sample Collection Time | Depth to Groundwater (ft) | Depth to LNAPL (ft) | LNAPL Thickness (ft) |
|---|---|---|---|
| 10/17/95 1202 HRS | 26.68' | 21.59' | 5.09' |
| 1339 HRS | 25.56' | 22.88' | 2.68' |
| 1342 HRS | 25.42' | 22.67' | 2.75' |
| 1403 HRS | 25.03' | 22.74' | 2.29' |
| 1413 HRS | 24.73' | 22.31' | 2.42' |
| 1459 HRS | 24.62' ↓ | 22.06' | ~~2.67'~~ 2.56 |
| 1633 HRS | 24.95' ↑ | 21.93' | 3.02' |
| | | | |
| 10/26/95 / 1820 HRS | 23.33' | 23.23' | .10' |
| 10/29 / 1900 HRS | 24.00' | 23.09 | .95' |
| 10/30 / 1630 HRS | 24.38' | 22.94' | 1.44' |
| 10/31 / 1330 HRS | 24.74' | 22.86' | 1.88' |
| | | | |
| | | | |

BAILDOWN.RS (G462201-1001 DISK)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data



Site: EDWARDS AFB

Start Date: 10/17/95

Test Type: Skimming

Operators: EASTEP/KITTEL/WOOLFE

| Date/Time | Run Time | LNAPL Recovery (volume collected in time period) | Groundwater Recovery (volume collected in time period) |
|---|---|---|---|
| 10/17/95/1154 | | STARTED SKIMMING (USED PARASTOLIC PUMP) | |
| /1718 | | 1.58 GAL of Fuel | — |
| /1746 | | 1.84 GAL of Fuel | — |
| /1915 | | 1.84 GAL of Fuel | |
| /1928 | | .39 GAL of Fuel | |
| 2353 TO | | | |
| 0012 | | .33 GAL of Fuel | |
| ~~10/18/95/0719~~ | | ~~.35 GAL of Fuel~~ | ~~.34 GAL of WATER~~ |
| 10/18/95/0719 | | 15.43 GAL | 7.74 GAL |
| 10/18/95/1830 | | 23.26 GAL | |
| 10/19/95/0630 | | 6.32 GAL | |
| 10/19/95/1155 | | 3.02 GAL | |
| 10/19/95/1600 | | 2.40 GAL | |
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SLURPPT.DS3 (G462201-1001 DISK)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of ___

Site: EDWARDS AFB

Start Date: 10/20/95

Test Type: BIOSLURPER.

Operators: EASTEP/WOOLFE

| Date/Time | Run Time | LNAPL Recovery (volume collected in time period) | Groundwater Recovery (volume collected in time period) |
|---|---|---|---|
| 10/20/95 / 1130 | 0 | 0 | 0 |
| 1210 | | 3.09 GALS PUMPED | |
| 1243 | | 4.4 GALS PUMPED | |
| 1405 | | 7.76 GALS. PUMPED | |
| 1625 | | 12.14 GALS PUMPED | |
| 1706 | | 3.43 GALS PUMPED | |
| 2035 | | 15.58 GALS PUMPED | - |
| 2044 | | ——— | RATE= 4L/2min 12SEC. - METER= 169 GALS |
| 10/20/95 / 2048 | | 2.11 GALS PUMPED | ——— |
| ——— | — | ——— | ——— |
| 10/21/95 / 0551 | | 36.1 GAL PUMPED | ——— |
| 0600 | | ——— | RATE= 4L/2min 13SEC. - METER= 422.4 GALS |
| 1011 | | 19.5 GALS PUMPED | RATE= 4L/2min 26SEC. - METER= 549.2 GALS |
| 1436 | | 11.6. GALS PUMPED | ——— |
| 10/21/95 / 2037 | | 8.7 GALS PUMPED | |
| ——— | — | ——— | ——— |
| 10/22/95 / 0956 | | 12.0 GALS PUMPED SINCE RESTART @ 0800 HRS | RATE= 4L/2min 12SEC. - METER= 893.2 GALS |
| 1510 | | 11.8 GALS PUMPED | RATE= 4L/2min 23SEC - METER= 1025.8 GALS |
| 10/22 2030 | | 10.5 GALS PUMPED | RATE= 4L/2min 23SEC. METER= 1100.9 GALS |
| ——— | — | ——— | ——— |
| 10/23/95 / 1325 | | 11.0 GALS PUMPED | RATE= — METER= 1265 GALS |
| 10/23 / 1500 | | 8.2 GALS PUMPED | RATE= 4L/2min 20SEC - METER= 1391.7 GALS |

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data



Site: EDWARDS AFB

Start Date: 10/20/95

Test Type: BioSlurper

Operators: EASTEP/Woolfe

| Date/Time | Run Time | LNAPL Recovery (volume collected in time period) | Groundwater Recovery (volume collected in time period) |
|---|---|---|---|
| 10/23/2138 | | 10 gals Pumped | METER = 1511 gals |
| 10/24/0916 | | 17.2 gals Pumped | RATE = 4L/2min 22sec. METER = 1824.6 gal |
| 10/24/1431 | | 9.6 gals Pumped | RATE = 5 ~~4~~L/3min 20 sec. METER = 1949.9 gals |
| 10/24/1816 | | 5.7 gals Pumped | ——— |
| 10/24/2000 | | ——— | RATE = — METER = 2073.5 gals |
| 10/25/0845 | | 44 gals Pumped | RATE = 4L/3min 11sec. METER = 2384.3 gal |
| 10/25/1200 | | 25.3 gals Pumped | RATE = 4L/3min 8sec. METER = 2446.5 gals |
| ——— | ——— | ——— | ——— |
| ——— | ——— | ——— | ——— |
| | | | Before START UP METER = 2504.6 gal |
| 10/31/1730 | | 10.0 gals Pumped | RATE = 4L/2min 8sec. METER = 2563.6 gals |
| 10/31/2130 | | 13.9 gals Pumped | RATE = 4L/2min 27sec METER = 2690.4 gals |
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# PILOT TEST PUMPING DATA

Site: EDWARDS AFB

Start Date: 10/20/95

Operators: EASTEP/ubolte

Start Time: 1130 HRS

Test Type: BioSLURPER / SKimming

Well ID: 24

Depth to Groundwater: 24.95'

Depth to Fuel: 21.93'

Depth of Tube: 23'3½"

| Date/Time START 1130 10/20/95 | Run Time | Vapor Extraction: Stack Flow (in $H_2O$) | Vapor Extraction: WELL VAC. " H2O | Vapor Extraction: Flowrate (scfm) | Pump Stack Temp (°C) | Pump Head Vacuum (in Hg) | % PROPANE | Comments |
|---|---|---|---|---|---|---|---|---|
| 10/20/95 / 2044 | | .015" | 6" | | NA | 20" | — | |
| 10/21/95 / 0600 | | .006" | 6.3" | | NA | 20" | 81% | |
| 10/21 / 1011 | | .015" | — | | NA | 20" | 81% | |
| 10/21 / 2037 | | .013 | 6.5" | | NA | 20" | 80% | |
| 10/22 / 0956 | | .005 | 6.5" | | NA | 20" | 74% | |
| 10/22 / 1510 | | .005 | — | | NA | 19.8" | 73% | |
| 10/22 / 2030 | | — | 6.5" | | NA | 20" | 70% | |
| 10/23 / 1325 | | .01" | 6.5" | | NA | 20" | 68% | |
| 10/23 / 1500 | | .008" | — | | NA | 20" | 66% | |
| 10/23 / 2138 | | .005" | 6.5" | | NA | 21" | 64% | |
| 10/24 / 0916 | | Some Flow But Not Readable | 6.3" | | NA | 16" | 60% | |
| 10/24 / 1431 | | .013" | — | | NA | 17" | 58% | |
| 10/24 / 2000 | | .005" | 6.0 | | NA | 16.5" | 56% | |
| 10/25 / 0845 | | .005" | 6.0" | | NA | 16" | 52% | |
| 10/25 / 1200 | | .01 | 6.0" | | NA | 15.5" | 52% | |
| SKimming TEST | | | — | — | ~~NA~~ | — | — | — |
| 10/25 / 1830 | | .0 | — | | NA | 12.5 | | |
| 10/25 / 1900 | | .005" | — | | NA | 13" | 51% | |

# APPENDIX E

# SOIL GAS PERMEABILITY TEST RESULTS

## Record Sheet for Air Permeability Test

| | |
|---|---|
| Site EDWARDS AFB | Monitoring Point A |
| Blower Type 7.5 SLURPER | Distance from Vent Well 10' |
| Depth of Point 10'-15'-20' | Recorded by Jon 7 Eastep |

| Time | G MP1 | B MP2 | R MP3 | Time | MP1 | MP2 | MP3 |
|---|---|---|---|---|---|---|---|
| -0- | 0 | 0 | 0 | | | | |
| 1 | .35 | 2.5 | 3.5 | | | | |
| 2 | 1.0 | 3.6 | 5.0 | | | | |
| 3 | 1.25 | 4.2 | 5.2 | | | | |
| 4 | 1.25 | 4.1 | 5.1 | | | | |
| 5 | 1.25 | 4.4 | 5.5 | | | | |
| 7 | 1.35 | 4.6 | 5.8 | | | | |
| 8 | 1.40 | 4.8 | 5.9 | | | | |
| 9 | 1.43 | 4.9 | 6.0 | | | | |
| 11 | 1.45 | 5.0 | 6.0 | | | | |
| 13 | 1.50 | 5.0 | 6.1 | | | | |
| 15 | 1.50 | 5.0 | 6.1 | | | | |
| 17 | 1.50 | 5.0 | 6.1 | | | | |
| 20 | 1.50 | 5.0 | 6.1 | | | | |
| 30 | 1.50 | 5.0 | 6.1 | | | | |
| 40 | 1.50 | 5.0 | 6.1 | | | | |
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WELL VACUUM 5 MIN = 5" Hg 40 MIN = 5.5" Hg
10 MIN = 5" Hg
20 MIN = 5" Hg
30 MIN = 5" Hg

AIRPERM.RS (G-62201-1001 DISK)

| Record Sheet for Air Permeability Test | | | | | | | |
|---|---|---|---|---|---|---|---|
| Site EDWARDS AFB | | | | Monitoring Point B | | | |
| Blower Type 7.5 SLURPER | | | | Distance from Vent Well 20' | | | |
| Depth of Point 10'-15'-20' | | | | Recorded by Woolfe | | | |
| Time | G MP1 | B MP2 | R MP3 | Time | MP1 | MP2 | MP3 |
| -0- | 0 | 0 | 0 | | | | |
| 1. | .20 | .30 | .50 | | | | |
| 2 | — | — | — | | | | |
| 3 | .45 | .70 | 1.0 | | | | |
| 4 | — | — | — | | | | |
| 5 | .50 | .75 | 1.5 | | | | |
| 6 | — | — | — | | | | |
| 7 | .50 | .80 | 1.10 | | | | |
| 8 | — | — | — | | | | |
| 9 | .55 | .85 | 1.15 | | | | |
| 10 | — | — | — | | | | |
| 12 | .55 | .85 | 1.20 | | | | |
| 14 | .55 | .90 | 1.20 | | | | |
| 16 | .65 | .90 | 1.25 | | | | |
| 18 | .65 | .85 | 1.25 | | | | |
| 20 | .65 | .90 | 1.25 | | | | |
| 25 | .60 | .90 | 1.25 | | | | |
| ~~30~~ | — | — | — | | | | |
| 35 | .60 | .95 | 1.30 | | | | |
| ~~40~~ | — | — | — | | | | |
| 45 | .60 | .95 | 1.30 | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| Record Sheet for Air Permeability Test | |
|---|---|
| Site EDW | Monitoring Point C |
| Blower Type 7.5 SLURPER | Distance from Vent Well 30' |
| Depth of Point 10'-15'-20' | Recorded by Woolfe |

| Time | G MP1 | B MP2 | R MP3 | Time | MP1 | MP2 | MP3 |
|---|---|---|---|---|---|---|---|
| -0- | 0 | 0 | ~~5~~ 0 | | | | |
| 1 | — | — | — | | | | |
| 2 | .24 | .25 | .25 | | | | |
| 3 | — | — | — | | | | |
| 4 | .25 | .30 | .35 | | | | |
| 5 | — | — | — | | | | |
| 6 | .25 | .35 | .35 | | | | |
| 7 | — | — | — | | | | |
| 8 | .30 | .35 | .40 | | | | |
| 9 | .30 | .40 | | | | | |
| 10 | .40 | .40 | .40 | | | | |
| 12 | RMW .30 | .40 | .40 | | | | |
| 14 | .35 | .45 | .40 | | | | |
| 16 | .35 | .45 | .45 | | | | |
| 18 | .35 | .45 | .45 | | | | |
| 20 | .35 | .45 | .45 | | | | |
| 25 | .35 | .40 | .45 | | | | |
| ~~30~~ | — | — | — | | | | |
| 35 | .35 | .45 | .45 | | | | |
| ~~40~~ | — | — | — | | | | |
| 45 | .35 | .45 | .45 | | | | |
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# APPENDIX F

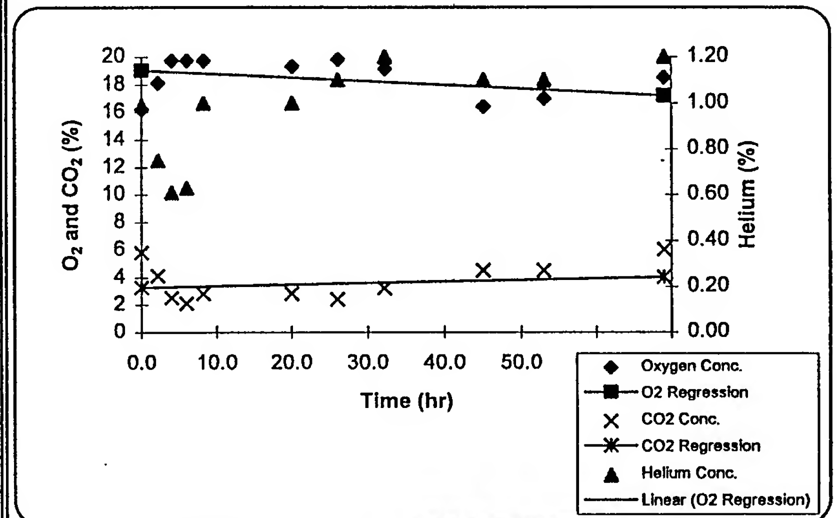
# IN SITU RESPIRATION TEST RESULTS

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPA-Green **Depth of M.P. (ft):** 10

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 16.20 | 5.80 | 0.99 |
| 10/28/95 12:10 | 2.2 | 18.10 | 4.10 | 0.75 |
| 10/28/95 14:00 | 4.0 | 19.70 | 2.50 | 0.61 |
| 10/28/95 16:00 | 6.0 | 19.70 | 2.10 | 0.63 |
| 10/28/95 18:10 | 8.2 | 19.70 | 2.80 | 1.00 |
| 10/29/95 6:00 | 20.0 | 19.30 | 2.80 | 1.00 |
| 10/29/95 12:00 | 26.0 | 19.80 | 2.40 | 1.10 |
| 10/29/95 18:10 | 32.2 | 19.10 | 3.20 | 1.20 |
| 10/30/95 7:00 | 45.0 | 16.40 | 4.50 | 1.10 |
| 10/30/95 15:00 | 53.0 | 17.00 | 4.50 | 1.10 |
| 10/31/95 7:00 | 69.0 | 18.50 | 6.00 | 1.20 |
| | | | | |
| | | | | |




| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.0262 | 0.0109 |
| *Intercept* | 19.0145 | 3.2566 |
| *Determination Coef.* | 0.1150 | 0.0294 |
| *No. of Data Points.* | 10 | 10 |

## $O_2$ Utilization Rate

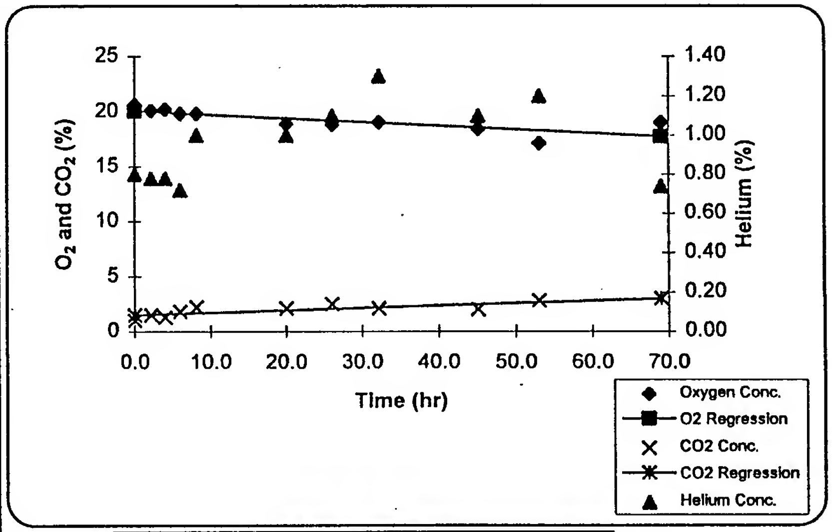
Ko 0.000 %/min
0.026 %/hr
0.628 %/day

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPA-Blue **Depth of M.P. (ft):** 15

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.60 | 1.00 | 0.80 |
| 10/28/95 12:10 | 2.2 | 20.10 | 1.50 | 0.78 |
| 10/28/95 14:00 | 4.0 | 20.20 | 1.30 | 0.78 |
| 10/28/95 16:00 | 6.0 | 19.80 | 1.80 | 0.72 |
| 10/28/95 18:10 | 8.2 | 19.80 | 2.20 | 1.00 |
| 10/29/95 6:00 | 20.0 | 18.90 | 2.10 | 1.00 |
| 10/29/95 12:00 | 26.0 | 18.80 | 2.50 | 1.10 |
| 10/29/95 18:10 | 32.2 | 19.00 | 2.10 | 1.30 |
| 10/30/95 7:00 | 45.0 | 18.40 | 2.00 | 1.10 |
| 10/30/95 15:00 | 53.0 | 17.10 | 2.80 | 1.20 |
| 10/31/95 7:00 | 69.0 | 19.00 | 3.00 | 0.74 |
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

Ko 0.001 %/min
0.033 %/hr
0.804 %/day

| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.0335 | 0.0219 |
| *Intercept* | 20.0538 | 1.4978 |
| *Determination Coef.* | 0.6175 | 0.7010 |
| *No. of Data Points.* | 11 | 11 |

# In Situ Respiration Test

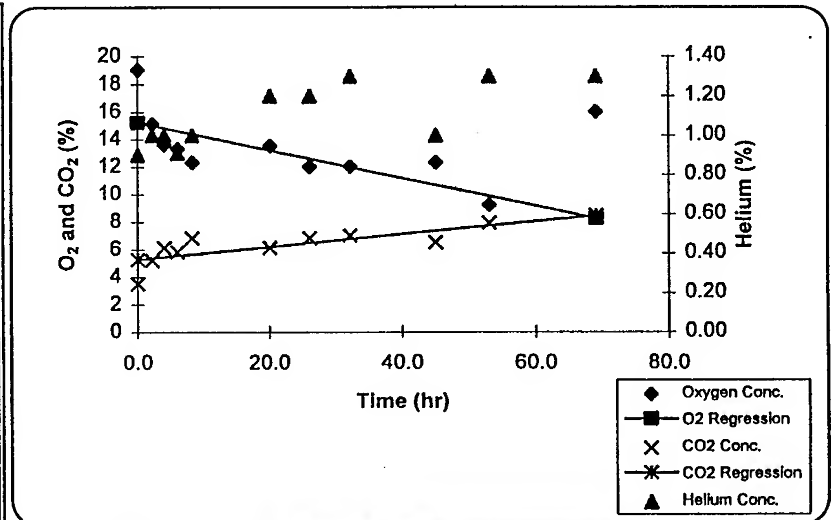
Date: 1/2/96

Site Name: Edwards AFB, CA

Monitoring Point: MPA-Red

Depth of M.P. (ft): 20

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 19.00 | 3.50 | 0.90 |
| 10/28/95 12:10 | 2.2 | 15.10 | 5.20 | 1.00 |
| 10/28/95 14:00 | 4.0 | 13.60 | 6.10 | 1.00 |
| 10/28/95 16:00 | 6.0 | 13.30 | 5.80 | 0.91 |
| 10/28/95 18:10 | 8.2 | 12.30 | 6.80 | 1.00 |
| 10/29/95 6:00 | 20.0 | 13.50 | 6.10 | 1.20 |
| 10/29/95 12:00 | 26.0 | 12.00 | 6.80 | 1.20 |
| 10/29/95 18:10 | 32.2 | 12.00 | 7.00 | 1.30 |
| 10/30/95 7:00 | 45.0 | 12.30 | 6.50 | 1.00 |
| 10/30/95 15:00 | 53.0 | 9.20 | 7.90 | 1.30 |
| 10/31/95 7:00 | 69.0 | 16.00 | 8.30 | 1.30 |
| | | | | |
| | | | | |




| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.1008 | 0.0464 |
| *Intercept* | 15.2106 | 5.2585 |
| *Determination Coef.* | 0.5617 | 0.5391 |
| *No. of Data Points.* | 10 | 10 |

## $O_2$ Utilization Rate

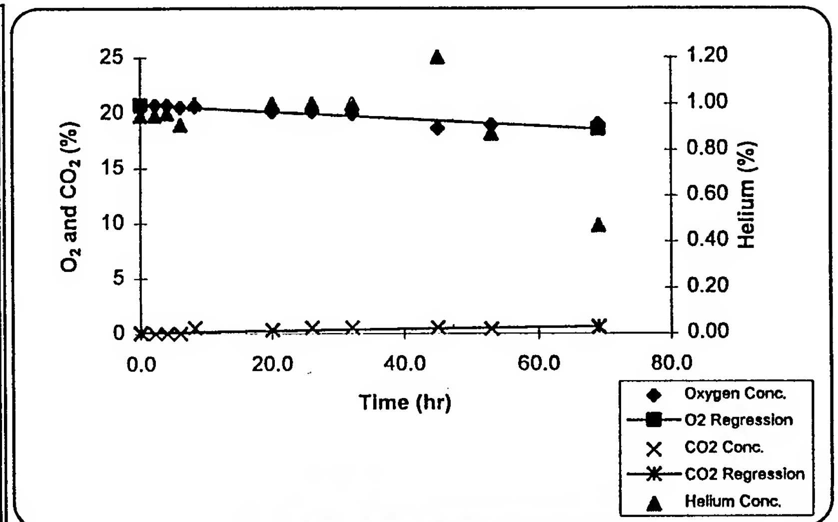
Ko 0.002 %/min
0.101 %/hr
2.419 %/day

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPB-Green **Depth of M.P. (ft):** 10

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.80 | 0.00 | 0.95 |
| 10/28/95 12:10 | 2.2 | 20.70 | 0.00 | 0.95 |
| 10/28/95 14:00 | 4.0 | 20.70 | 0.00 | 0.96 |
| 10/28/95 16:00 | 6.0 | 20.50 | 0.00 | 0.91 |
| 10/28/95 18:10 | 8.2 | 20.60 | 0.50 | 1.00 |
| 10/29/95 6:00 | 20.0 | 20.10 | 0.30 | 1.00 |
| 10/29/95 12:00 | 26.0 | 20.10 | 0.50 | 1.00 |
| 10/29/95 18:10 | 32.2 | 19.90 | 0.50 | 1.00 |
| 10/30/95 7:00 | 45.0 | 18.60 | 0.50 | 1.20 |
| 10/30/95 15:00 | 53.0 | 18.90 | 0.40 | 0.87 |
| 10/31/95 7:00 | 69.0 | 19.00 | 0.50 | 0.47 |
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

Ko 0.001 %/min
0.032 %/hr
0.772 %/day

| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.0322 | 0.0074 |
| *Intercept* | 20.7669 | 0.1122 |
| *Determination Coef.* | 0.8716 | 0.5220 |
| *No. of Data Points.* | 11 | 11 |

# In Situ Respiration Test

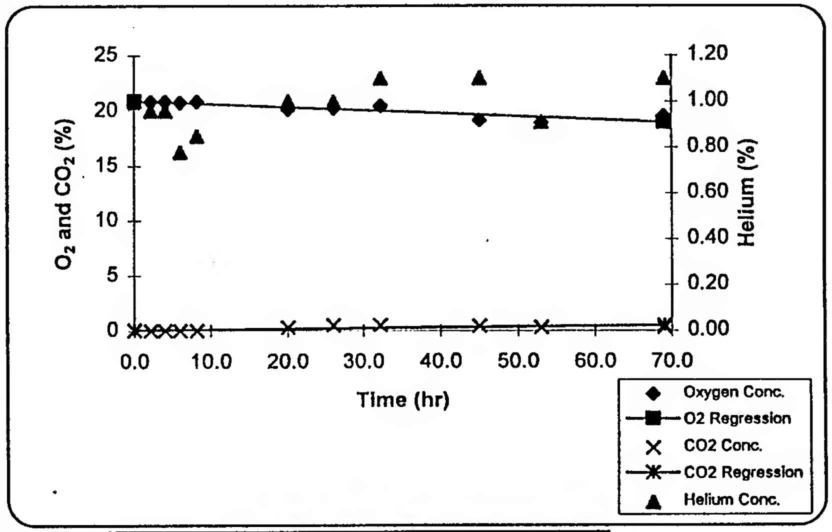
**Date:** 1/2/96

**Site Name:** Edwards AFB, CA

**Monitoring Point:** MPB-Blue

**Depth of M.P. (ft):** 15

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.90 | 0.00 | 1.00 |
| 10/28/95 12:10 | 2.2 | 20.80 | 0.00 | 0.96 |
| 10/28/95 14:00 | 4.0 | 20.80 | 0.00 | 0.96 |
| 10/28/95 16:00 | 6.0 | 20.70 | 0.00 | 0.78 |
| 10/28/95 18:10 | 8.2 | 20.80 | 0.00 | 0.85 |
| 10/29/95 6:00 | 20.0 | 20.10 | 0.30 | 1.00 |
| 10/29/95 12:00 | 26.0 | 20.20 | 0.50 | 1.00 |
| 10/29/95 18:10 | 32.2 | 20.40 | 0.50 | 1.10 |
| 10/30/95 7:00 | 45.0 | 19.10 | 0.40 | 1.10 |
| 10/30/95 15:00 | 53.0 | 18.90 | 0.30 | 0.91 |
| 10/31/95 7:00 | 69.0 | 19.50 | 0.30 | 1.10 |
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

| | | |
|---|---|---|
| Ko | 0.000 | %/min |
| | 0.028 | %/hr |
| | 0.667 | %/day |

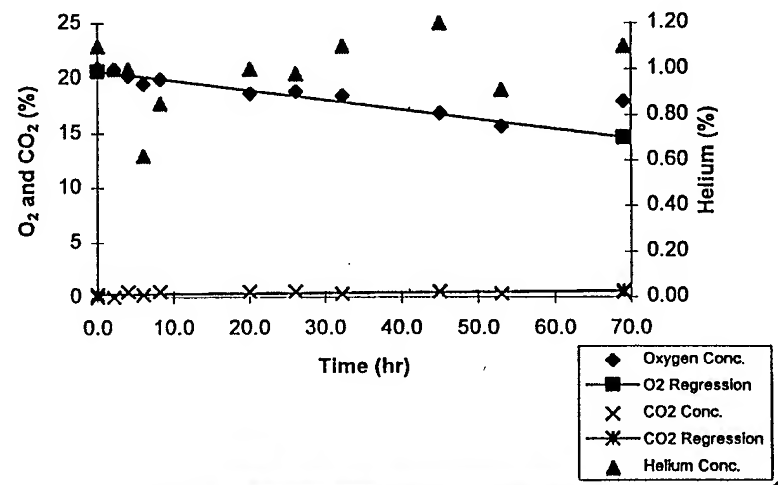
| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.0278 | 0.0063 |
| *Intercept* | 20.8708 | 0.0570 |
| *Determination Coef.* | 0.7961 | 0.4796 |
| *No. of Data Points.* | 11 | 11 |

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPB-Red **Depth of M.P. (ft):** 20

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.90 | 0.00 | 1.10 |
| 10/28/95 12:10 | 2.2 | 20.80 | 0.00 | 1.00 |
| 10/28/95 14:00 | 4.0 | 20.20 | 0.50 | 1.00 |
| 10/28/95 16:00 | 6.0 | 19.50 | 0.20 | 0.62 |
| 10/28/95 18:10 | 8.2 | 19.90 | 0.50 | 0.85 |
| 10/29/95 6:00 | 20.0 | 18.60 | 0.50 | 1.00 |
| 10/29/95 12:00 | 26.0 | 18.80 | 0.50 | 0.98 |
| 10/29/95 18:10 | 32.2 | 18.40 | 0.30 | 1.10 |
| 10/30/95 7:00 | 45.0 | 16.80 | 0.50 | 1.20 |
| 10/30/95 15:00 | 53.0 | 15.60 | 0.30 | 0.91 |
| 10/31/95 7:00 | 69.0 | 17.90 | 0.40 | 1.10 |
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

| | | |
|---|---|---|
| Ko | 0.001 | %/min |
| | 0.088 | %/hr |
| | 2.117 | %/day |

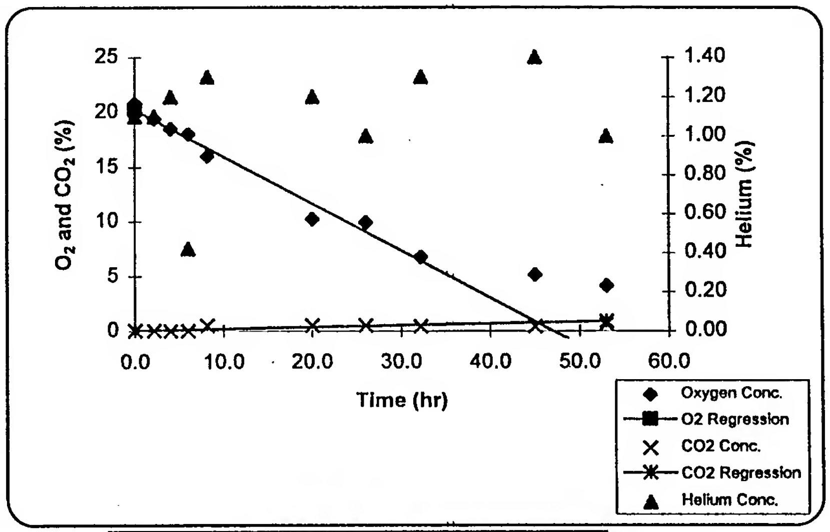
| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.0882 | 0.0042 |
| *Intercept* | 20.6830 | 0.2474 |
| *Determination Coef.* | 0.9490 | 0.1489 |
| *No. of Data Points.* | 10 | 10 |

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPC-Green **Depth of M.P. (ft):** 10

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.80 | 0.00 | 1.10 |
| 10/28/95 12:10 | 2.2 | 19.40 | 0.03 | 1.10 |
| 10/28/95 14:00 | 4.0 | 18.50 | 0.00 | 1.20 |
| 10/28/95 16:00 | 6.0 | 18.00 | 0.00 | 0.42 |
| 10/28/95 18:10 | 8.2 | 16.00 | 0.50 | 1.30 |
| 10/29/95 6:00 | 20.0 | 10.20 | 0.50 | 1.20 |
| 10/29/95 12:00 | 26.0 | 9.90 | 0.50 | 1.00 |
| 10/29/95 18:10 | 32.2 | 6.70 | 0.40 | 1.30 |
| 10/30/95 7:00 | 45.0 | 5.10 | 0.40 | 1.40 |
| 10/30/95 15:00 | 53.0 | 4.10 | 0.60 | 1.00 |
| | | | | |
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

Ko 0.007 %/min
0.431 %/hr
10.333 %/day

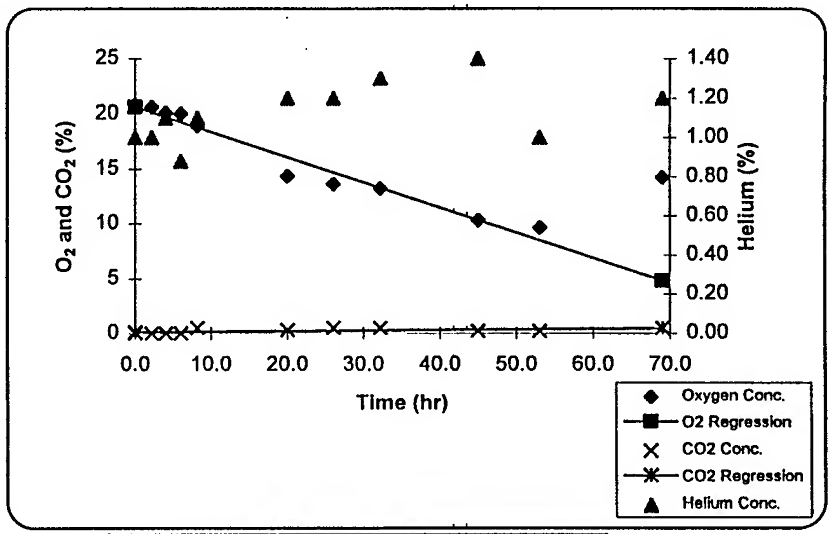
| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.4306 | 0.0159 |
| *Intercept* | 20.2387 | 0.0453 |
| *Determination Coef.* | 0.9802 | 0.5808 |
| *No. of Data Points.* | 8 | 8 |

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPC-Blue **Depth of M.P. (ft):** 15

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.80 | 0.00 | 1.00 |
| 10/28/95 12:10 | 2.2 | 20.60 | 0.00 | 1.00 |
| 10/28/95 14:00 | 4.0 | 20.10 | 0.00 | 1.10 |
| 10/28/95 16:00 | 6.0 | 20.00 | 0.00 | 0.88 |
| 10/28/95 18:10 | 8.2 | 18.90 | 0.50 | 1.10 |
| 10/29/95 6:00 | 20.0 | 14.30 | 0.30 | 1.20 |
| 10/29/95 12:00 | 26.0 | 13.60 | 0.50 | 1.20 |
| 10/29/95 18:10 | 32.2 | 13.20 | 0.50 | 1.30 |
| 10/30/95 7:00 | 45.0 | 10.30 | 0.20 | 1.40 |
| 10/30/95 15:00 | 53.0 | 9.60 | 0.20 | 1.00 |
| 10/31/95 7:00 | 69.0 | 14.20 | 0.50 | 1.20 |
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

Ko 0.004 %/min
0.229 %/hr
5.505 %/day

| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -0.2294 | 0.0048 |
| *Intercept* | 20.6475 | 0.1248 |
| *Determination Coef.* | 0.9634 | 0.1726 |
| *No. of Data Points.* | 10 | 10 |

# In Situ Respiration Test

**Date:** 1/2/96 **Site Name:** Edwards AFB, CA

**Monitoring Point:** MPC-Red-Blue **Depth of M.P. (ft):** 5

| Date/Time (mm/dd/yr hr:min) | Time (hr) | Oxygen (%) | Carbon Dioxide (%) | Helium (%) |
|---|---|---|---|---|
| 10/28/95 10:00 | 0.0 | 20.60 | 0.00 | 0.99 |
| 10/28/95 12:10 | 2.2 | 16.50 | 0.05 | 1.00 |
| 10/28/95 14:00 | 4.0 | 9.70 | 0.05 | 1.20 |
| 10/28/95 16:00 | 6.0 | 14.80 | 0.50 | 1.00 |
| 10/28/95 18:10 | 8.2 | 4.00 | 0.50 | 1.20 |
| 10/29/95 6:00 | 20.0 | 4.90 | 0.80 | 1.00 |
| 10/29/95 12:00 | 26.0 | 3.30 | 1.50 | 1.00 |
| | | | | |
| | | | | |
| | | | | |
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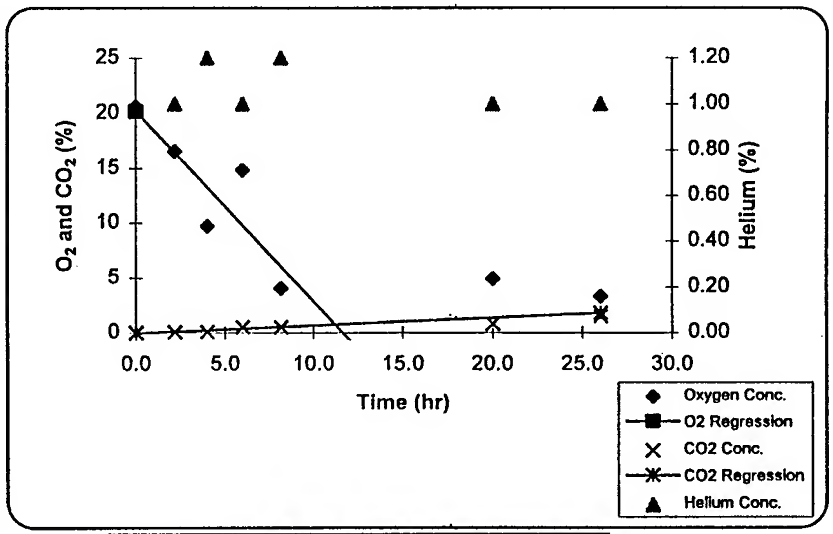
| | | | | |
| | | | | |




## $O_2$ Utilization Rate

Ko 0.029 %/min
1.738 %/hr
41.724 %/day

| Regression Lines | $O_2$ | $CO_2$ |
|---|---|---|
| *Slope* | -1.7385 | 0.0717 |
| *Intercept* | 20.1899 | -0.0716 |
| *Determination Coef.* | 0.7452 | 0.7956 |
| *No. of Data Points.* | 5 | 5 |

# APPENDIX G

## SUMMARY OF OPERATIONAL PROBLEMS WITH THE ICE

**DEPARTMENT OF THE AIR FORCE**
HEADQUARTERS AIR FORCE FLIGHT TEST CENTER (AFMC)
EDWARDS AIR FORCE BASE, CALIFORNIA

19 April 1996

AFFTC/EMRR
5 E. Popson Avenue
Edwards AFB, CA 93524-1130

Mr. Jeff Kittel
c/o Battelle
505 King Ave.
Columbus, OH 43201

Dear Mr. Kittel,

This letter is to address our specific problems and general opinion we have concerning the Remediation Services International (RSI) Internal Combustion Engine (ICE) which is used as an air treatment unit for our Bioslurper demonstration project. We have been operating the unit since the demonstration's beginning in August 1995.

The following is a synopsis of the maintenance performed on the ICE unit since its inception.

10/30/95: Knock out tank leaks water.
Corrective Action: The water level sight glass broke. The sight glass was made of thin plastic and could not withstand the cold weather temperatures. We closed the sight glass shut off valves that discontinued the use of the sight glass.

11/18/95: Unit will not start.
Corrective action: We drained water from the fixed line under the ICE blower unit. The hydrophobic air inlet filter was replaced.

12/20/95: The ICE unit was not vacuuming vapor from the unit's knock-out tank..
Corrective Action: RSI was notified of the situation. A RSI technician installed new software.

03/05/96: Discovered the unit would not operate past 800 RPM.
Corrective Action: The first of two catalytic converters was plugged. The converter was removed. RSI commented that since the converter clogged, the jet-fuel vapors we were processing were probably causing the same effect to the heads and valves of the engine, and that an overhaul may be in order.

04/05/96: The ICE unit was making constant chattering sounds.
Corrective Action: The broken bracket on the engine-to-generator fan belt shroud was rewelded.

Our overall opinion of the unit is favorable (with the updated software version installed). However, this is dependent on the actual need for an overhaul due to the burning of jet-fuel vapors. The ICE/vapor compatibility is very important in this kind of application, and at this time that compatibility may be in question. I would ultimately require that an ICE have a MTBO of greater than 1,400 hours, as our unit currently has. We received the unit with approximately 450 hours on the Hobbs meter.

If you require any further information, please feel free to contact me at (805)277-1474.

Sincerely,

David E Steckel

DAVID E. STECKEL, Project Manager
Environmental Restoration Division